# Part I
# General Provisions

## Purpose (A)

The purpose of the guidelines and procedures in this handbook is to control the possession, use, and transfer of sources of radiation by NRC personnel in such a manner that the dose to an individual does not exceed the standards of radiation protection prescribed herein and are maintained as low as reasonably achievable (ALARA). This handbook also provides standards to protect NRC employees from radiation hazards during licensing, inspection, enforcement, and other regulatory activities including visits to nuclear facilities in other countries.

## Training (B)

Each program office and region shall establish provisions for radiation safety training commensurate with the duties of their employees. In general, the training frequency should be at least once every 2 years. Employees requesting power reactors and certain fuel cycle facilities to accept NRC site access training in place of their own training for unescorted access will need training every 12 months. In addition, each office should provide discretionary training to ancillary personnel commensurate with their duties.

## Responsibilities of the Radiation Safety Officers (RSOs) (C)

RSOs shall—

- Ensure that headquarters or regional office procedures implement the provisions of this directive. (1)

## Responsibilities of the Radiation Safety Officers (RSOs) (C) (continued)

- Review radiation exposure information on monitored employees in their headquarters or regional offices for overexposures and anomalies and distribute information to managers, as appropriate, to allow them to maintain the doses to their staff ALARA. The release of employee exposure information should be conducted with due regard for employee rights under the Privacy Act. (2)
- Furnish radiation exposure information to office directors or regional administrators, who have a need to know, upon request. (3)
- Furnish radiation exposure data to current and former employees as required by this directive. (4)
- Maintain prior dose records in accordance with Part II (B)(1) of this handbook, and prepare records for each planned special exposure in accordance with 10 CFR 20.2105(a). (5)
- Furnish reports of overexposures to the appropriate office director or regional administrator. (6)
- Participate in the annual RSO counterpart meeting, providing copies of procedures and records, as requested, and performing peer reviews of written and implemented radiation safety programs. (7)
- Determine, in consultation with an employee's immediate supervisor, when it is necessary or desirable to furnish bioassay services to an employee, and assist the employee with obtaining bioassay services, as appropriate. (8)

## Responsibilities of Employees (D)

Employees shall—

- Comply with standards and procedures established by the NRC that are applicable to their own actions and conduct. (1)
- Make every reasonable effort to maintain the sum of internal and external radiation exposure and the release of radioactive materials in effluents to unrestricted areas ALARA. (2)

## Responsibilities of Employees (D) (continued)

- Use safety and personal protective equipment and other devices necessary for their protection that the employee is provided or instructed to use by the NRC or the radiation protection staff at the site. (3)
- Use correct, safe practices in all official activities and follow licensee radiation safety procedures during site visits and inspections. (4)
- Report any observed radiation hazards to a supervisor as soon as reasonably possible. (5)
- Inform their RSO of any occupational exposure history in accordance with this management directive and applicable office procedures. (6)
- Make every effort to exchange dosimeters, and report lost or damaged dosimeters, in a timely manner. (7)
- If female, inform their RSO if they declare in writing to their immediate supervisor that they are pregnant in accordance with Part II(G) of this handbook. (8)

# Part II
# Permissible Doses, Levels, and Concentrations

## Occupational Dose Limits for Adults (A)

The occupational dose to individual adult employees shall be limited to the following doses:

**Table I–1 Occupational Dose Limits for Adults**

| Dose | Routine Rem/Year | Planned Special Rem/Year | Planned Special Rem/Lifetime |
|---|---|---|---|
| LDE | 15 | 15 | 75 |
| SDE, WB | 50 | 50 | 250 |
| SDE, ME | 50 | 50 | 250 |
| TEDE | 5 | 5 | 25 |
| TODE | 50 | 50 | 250 |

| | |
|---|---|
| LDE | Lens (eye) dose equivalent measured at a dose depth of 300 mg/cm². |
| SDE, WB | Shallow dose equivalent to the skin of the whole body measured at a dose depth of 7 mg/cm² averaged over 1 cm². |
| SDE, ME | Shallow dose equivalent to the skin of the maximally exposed extremity measured at a dose depth of 7 mg/cm² averaged over 1 cm². |
| TEDE | Total effective dose equivalent defined as the sum of the deep dose equivalent and the committed effective dose equivalent. |
| TODE | Total organ dose equivalent defined as the sum of the deep dose equivalent and the committed dose equivalent to the maximally exposed organ from sources internally deposited. |

## Determination of Prior Dose (B)

Before authorizing official duties likely to cause an employee to receive an occupational dose requiring monitoring pursuant to Part III of this handbook, the responsible headquarters office director or regional administrator shall ensure that—(1)

- The occupational radiation dose received by the employee during the current year has been determined. (a)
- An attempt has been made to determine the occupational dose that the employee has received over his or her lifetime. (b)

The NRC shall maintain records of prior dose for 75 years from the date of the creation of the record (see NUREG–0910, Schedule 2–22.5.a). (2)

Before allowing an individual to participate in a planned special exposure, the responsible region or headquarters program office shall obtain—(3)

- The individual's signed certificate, NRC Form 4, "Lifetime Occupational Exposure History," showing each period the individual was monitored for occupational exposure to radiation and the results of that monitoring. (a)
- A letter authorizing the planned special exposure signed by the individual and the individual's immediate supervisor, with organizational concurrence through the level of office director or regional administrator. (b)

In preparing the NRC Form 4, or a clear and legible record containing all the information required in NRC Form 4, NRC shall make a reasonable effort to obtain reports of the individual's previously accumulated occupational dose or a printout from the Radiation Exposure Information Reporting System (REIRS) database. The REIRS Privacy Act System of Records, NRC-27, contains additional information regarding records on individuals that are maintained in the system. For each period for which these reports are obtained, the dose shown in the report must be used in preparing NRC Form 4. The provisions of 10 CFR 20.2104(e) shall be observed if records are unavailable. The NRC shall retain and preserve records used in preparing NRC Form 4 and database records for 75 years from the date of the creation of the record or report (see NUREG–0910, Schedule 2–22.5.a and b). (4)

## Exposure of Individuals to Radioactive Materials in the Air (C)

It is assumed that an individual inhales radioactivity at the airborne concentration in which he or she is present unless respiratory protective equipment is used. To ascertain if the sum of external and internal dose is as low as reasonably achievable (ALARA), concentrations of radioactive materials in the air will be measured to detect and assess airborne radioactivity in restricted areas and, as appropriate, radioactivity in the body, excreted from the body, or any combination will be measured to detect and assess individual intakes of radioactivity by exposed individuals. (1)

To limit concentrations of radioactive materials in the air, process or other engineering controls will be used at NRC facilities, to the extent practicable. When it is impractical to apply engineering controls to limit concentrations of radioactive material in the air, other precautionary procedures, such as increased surveillance, limitation of working times, or the use of respiratory protection equipment, will be used to maintain the sum of internal and external exposures ALARA. The use of respiratory protection equipment shall be consistent with the provisions in 10 CFR 20.1703. (2)

## Planned Special Exposures (D)

The need for a planned special exposure is not anticipated but, if necessary, an office director or a regional administrator may authorize an adult employee to receive a planned special exposure, provided that the conditions specified in 10 CFR 20.1206 are satisfied.

## Occupational Dose Limits for Minors (E)

No individual who is under the age of 18 years shall receive an annual dose in excess of 10 percent of the limits of exposure to sources of radiation or radioactive material under the control of NRC (see Section (A) of this part for limits). Minors may not participate in planned special exposures.

## Dose Limits for Members of the Public (F)

No member of the public shall receive a dose in excess of 0.1 rem total effective annual dose equivalent from the sum of external and internal exposures from sources of radiation or radioactive material under the control of NRC. This excludes the dose contribution from any disposal of radioactive material into sanitary sewerage pursuant to Part IV of this handbook. Also, a dose from external sources in unrestricted areas must be less than 2 millirem in any 1 hour.

## Dose to an Embryo or a Fetus (G)

The dose to the embryo or fetus during the entire pregnancy of a woman who has declared in writing to her immediate supervisor that she is pregnant must not exceed 0.5 rem from the sum of exposure to sources external to the mother, intakes of radioactive material deposited in the mother, and intakes of radioactive material deposited in the embryo or fetus. If the dose to the declared pregnant worker has already exceeded 0.45 rem at the time of the declaration, the dose for the remainder of the pregnancy must be limited to 0.05 rem. Every effort should be made to avoid substantial variation above a uniform monthly exposure rate (i.e., about 55 millirem per month).

## Compliance With Dose Limits for Members of the Public (H)

NRC offices possessing radioactive material shall measure, as appropriate, radiation levels in unrestricted areas to demonstrate compliance with the dose limits to members of the public in Section (F) above. Compliance shall be demonstrated using methods consistent with those specified in 10 CFR 20.1302.

## Furnishing of Bioassay Services (I)

When the cognizant radiation safety officer (RSO), in consultation with an employee's immediate supervisor, determines that bioassay services are necessary or desirable, appropriate bioassay services shall be made available to the individual to aid in determining the extent of an individual's exposure to concentrations of radioactive material. Each office or region shall make provisions for obtaining bioassay services if the need arises.

# Part III
# Precautionary Procedures

## Surveys (A)

Surveys shall be made at NRC facilities as necessary to comply with the provisions of this handbook and to determine the extent of any radiation hazard that may be present. (1)

Instruments and equipment used for quantitative radiation measurements by NRC employees and/or at NRC facilities (e.g., dose rate measurements and effluent monitoring) shall be calibrated periodically for the radiation measured. (2)

## Personnel Monitoring (B)

NRC licensees are legally responsible for limiting workers' exposures to radioactive material in their possession in accordance with 10 CFR Part 20. This responsibility includes visitors as well as the licensee's employees. (1)

When NRC issues a dosimeter, it will be the primary dosimeter of record unless there is reason to believe that another dose measurement or estimate is more accurate; in which case, the more accurate dose shall be recorded. NRC headquarters office directors and regional administrators shall ensure that either personnel dosimetry equipment supplied by NRC or the licensee is issued to NRC employees and used during visits to facilities at which radioactive material is stored or used if any of the following criteria are met: (2)

- An employee is likely to exceed 10 percent of any of the limits listed in Part II (A) of this handbook. (a)
- Any employee under 18 years of age is likely to exceed 10 percent of the limits listed in Part II (E) of this handbook. (b)

## Personnel Monitoring (B) (continued)

- A declared pregnant employee is likely to exceed 10 percent of the limits listed in Part II (G) of this handbook. (c)

All NRC personnel dosimeters used to demonstrate compliance with the dose limits in this handbook shall comply with the provisions in 10 CFR 20.1501, including the use of an accredited dosimetry processor. Supplemental dosimeters, such as pocket ionization chambers and electronic dosimeters, may be used also. (3)

If monitoring is required and licensee dosimetry is used instead of NRC dosimetry, the dosimetry results shall be obtained from the licensee using NRC Form 525 or an equivalent procedure. The results shall be entered into the employee exposure database. (4)

The NRC is not required to make independent radiation measurements or duplicate radiation safety programs at facilities that are not under its direct control. NRC employees who visit facilities at which they may be exposed to radioactive materials may accept the measurements made by the facility personnel and rely on the radiation safety programs established at the facility. (5)

## Caution Signs, Labels, Signals, and Controls (C)

Unless a deviation is authorized by Director, Office of Nuclear Material Safety and Safeguards, caution signs, labels, signals, and controls will be used as specified in 10 CFR 20.1901, 20.1902, 20.1903, 20.1904, and 20.1905. (1)

A current copy of this handbook and any operating procedures applicable to work involving radiation or radioactive material will be conspicuously posted in appropriate locations of NRC facilities to ensure that employees who have the potential to receive an occupational exposure from NRC–controlled radiation sources shall observe these documents. If posting these documents is not practicable, a notice shall be posted that describes the documents and states where they may be examined. The office director or a designated representative shall keep these documents available for examination upon request. (2)

## Picking Up, Receiving, and Opening Packages (D)

Each region shall maintain and follow procedures consistent with the requirements specified in 10 CFR 20.1906 for safely picking up, receiving, and opening packages in which radioactive material is contained. Due consideration shall be given to special instructions for the type of package being opened. Unexpected packages received at NRC headquarters will be referred to Region I for appropriate action. The Region I radiation safety officer (RSO) or alternate RSO shall be informed when a package is forwarded.

## Instructions to Employees (E)

All employees who have the potential for receiving an occupational dose shall be advised and instructed—(1)

- About the storage, transfer, and use of radioactive materials, and about radiation levels associated with their assigned duties. (a)
- About the health protection problems associated with exposure to radioactive materials and radiation, precautions and procedures to minimize exposure, and the purposes and functions of protective devices employed. (b)
- To observe to the extent within the worker's control the applicable provisions of this handbook for the protection of personnel from exposure to radiation or radioactive materials associated with their assigned duties. (c)
- About their responsibility to promptly report any condition that may lead to or cause a violation of the provisions of this handbook or unnecessary exposure to radiation or to radioactive material. (d)
- About the appropriate response to warnings made in the event of any unusual occurrence or malfunction that may involve exposure to radiation or radioactive material. (e)
- About the results of monitoring for exposure to radiation or radioactive material on an annual basis. (f)

The extent of these instructions will be commensurate with the potential radiological health risk. (2)

## Instructions to Employees (E) (continued)

Each individual shall receive appropriate training before being issued a dosimeter, unless the individual will be escorted by someone with equivalent training. (3)

## Storage and Control of Radioactive Materials in Unrestricted Areas (F)

Radioactive materials stored by NRC in an unrestricted area shall be secured to prevent unauthorized removal from the place of storage. (1)

NRC staff shall control and maintain constant surveillance of radioactive material that is in an unrestricted area and not in storage. (2)

# Part IV
# Waste Disposal

## General Requirement (A)

No NRC facility shall dispose of radioactive material except under any of the following conditions:

- By transfer to an authorized recipient (1)
- As provided in Sections (B) and (C) of this part or in Part II (H) of this handbook (2)
- As otherwise provided in NRC regulations for licensees (3)

## Disposal of Radioactive Material by Release Into Sanitary Sewerage Systems (B)

Radioactive material may be discharged into a sanitary sewer system if the conditions specified in 10 CFR 20.2003 are satisfied. Care should be taken to comply with local and State regulatory requirements concerning the nonradioactive properties of materials discharged into a sanitary sewer system.

## Disposal of Specific Wastes (C)

NRC facilities may dispose of wastes specified in 10 CFR 20.2005 as if they are not radioactive.

## Mixed Waste (D)

The generation of mixed radiological and hazardous waste at NRC facilities will be avoided if at all possible. Any mixed waste generated will be managed and disposed of in accordance with all applicable Federal and State regulations.

## Records (E)

Records of any waste disposal made pursuant to this part will be maintained in accordance with Part V of this handbook.

# Part V
# Records, Reports, and Notifications

## Records of Surveys, Radiation Monitoring, and Disposal (A)

**General Provisions (1)**

The records required by this handbook will contain the units curie, rad, and rem, including multiples and subdivisions, and the units will be clearly indicated. Units of roentgen and disintegrations per minute (dpm) are acceptable on records of radiation and contamination surveys. The quantities on the records also will be clearly indicated as the total effective dose equivalent, the shallow dose equivalent, the deep dose equivalent, the eye dose equivalent, and the committed effective dose equivalent. The shallow dose equivalent pertains to both the maximum extremity and the skin of the whole body. (a)

The retention requirements of this directive and handbook are not intended to limit or reduce any other NRC record retention requirements. (b)

**Records of the NRC Radiation Protection Program (2)**

Historical records of the provisions specified in this directive and handbook, including any interpretations or deviations, shall be maintained by the Office of Nuclear Material Safety and Safeguards (NMSS), for 10 years in accordance with NUREG–0910, Schedule 1–2.2.b. (a)

Audits and other reviews of program content and implementation will be maintained in accordance with standard NRC record retention requirements. (b)

# Records of Surveys, Radiation Monitoring, and Disposal (A) (continued)

**Records of Surveys (3)**

Records showing the results of surveys and calibrations required by Part III (A) of this handbook are unscheduled and must be retained until a records disposition schedule is approved by the National Archives and Records Administration (NARA). (a)

The following records, when applicable to an individual, will be retained for 75 years from the date of the creation of the record (see NUREG–0910, Schedule 2–22.5.a). (b)

- Records of the results of surveys to determine the dose from external sources and used in the absence of or in combination with individual monitoring data in the assessment of individual dose equivalents. (i)
- Records of the results of measurements and calculations used to determine individual intakes of radioactive material and used in the assessment of internal dose. (ii)
- Records of the results of measurements and calculations used to evaluate the release of radioactive effluents to the environment. These records are unscheduled and must be retained until a records disposition schedule is approved by NARA. (iii)

**Records of Prior Dose (4)**

Records of prior dose will be prepared pursuant to Part II (B) of this handbook. (a)

Records of prior dose will be maintained for 75 years from the date of the creation of the record (see NUREG–0910, Schedule 2–22.5.a). (b)

**Records of Planned Special Exposures (5)**

For each planned special exposure of an NRC employee, the radiation safety officer (RSO) for that employee shall ensure that the records specified in 10 CFR 20.2105(a) are prepared. (a)

# Records of Surveys, Radiation Monitoring, and Disposal (A) (continued)

**Records of Planned Special Exposures (5) (continued)**

Records of planned special exposures will be maintained for 75 years from the date of the creation of the record (see NUREG–0910, Schedule 2–22.5.a). (b)

**Records of Individual Monitoring Results (6)**

NRC shall maintain records of doses received by NRC employees for whom monitoring was required and records of doses received during planned special exposures, accidents, and emergency conditions. These records will include the same information required by 10 CFR 20.2106(a). These records will be stored under the NRC's Privacy Act System of Records (NRC-27, "Radiation Exposure Information Reporting System [REIRS] Files"). (a)

Entries on the records specified in (a) above will cover periods not exceeding 1 calendar year. (b)

The records required by this section will be in a format similar to that of NRC Form 5, "Occupational Exposure Record for a Monitoring Period." (c)

The records required under this section shall be protected from public disclosure pursuant to the Privacy Act of 1974, as amended. (d)

NRC shall maintain records of dose to an embryo or a fetus with the records of dose to the declared pregnant woman. The declaration of pregnancy also will be kept on file but may be maintained separately from the dose records. Both records will be stored under the NRC's Privacy Act System of Records (NRC-27, REIRS). (e)

Records of individual monitoring results will be maintained for 75 years from the date of the creation of the record (see NUREG–0910, Schedule 2–22.5.a). (f)

Dosimeter and film badge processing reports will be maintained for 75 years from the date of the report (see NUREG–0910, Schedule 2–22.5.b). (g)

# Records of Surveys, Radiation Monitoring, and Disposal (A) (continued)

**Records of Dose to Individual Members of the Public (7)**

Each headquarters and regional office possessing radioactive material, other than quantities that are exempt from NRC regulations, shall maintain records sufficient to demonstrate compliance with the dose limit for individual members of the public. (a)

The records required by (a) above are unscheduled and must be retained until a records disposition schedule is approved by NARA. (b)

**Records of Waste Disposal (8)**

Records of waste disposal made pursuant to Part IV of this handbook are unscheduled and must be retained until a records disposition schedule is approved by NARA.

**Record Requirements (9)**

Each record required by this part shall be accumulated in locations formally designated as "official file stations" and retained in accordance with the applicable NARA-approved records disposition schedules contained in NUREG-0910, "NRC Comprehensive Records Disposition Schedule." The file custodian of these records shall maintain an updated files maintenance and disposition plan (NRC Form 306) for each respective official file station in accordance with Management Directive (MD) 3.53, "NRC Records Management Program," that includes the records schedule number and approved disposition for each record series maintained. These records are to be transferred to the Office of Information Resources Management (IRM) for storage when they become inactive or when they are 2 to 3 years old, whichever comes first. Any changes in the media used to store these records shall be coordinated with the NRC Records Officer (i.e., Chief, Information and Records Management Branch, IRM) to ensure that the records are properly scheduled and that the records are retained accordingly.

# Reports of Theft or Loss of Radioactive Material (B)

Headquarters and regional offices shall report by telephone to the NRC Operations Center under either of the following circumstances: (1)

- Immediately after discovering that any radioactive material in a quantity greater than 1000 times the quantity specified in 10 CFR 20.1001–2402, Appendix C, is lost, stolen, or missing under circumstances that an exposure could result to persons in unrestricted areas. (a)
- Within 30 days after discovering that any lost, stolen, or missing radioactive material in a quantity greater than 10 times the quantity specified in 10 CFR 20.1001–2402, Appendix C, is still missing. (b)

Within 30 days of reporting the lost, stolen, or missing radioactive material, the reporting office shall submit to the Director, NMSS, and the appropriate Deputy Executive Director for Operations a written report containing the following information: (2)

- A description of the radioactive material involved, including kind, quantity, chemical form, and physical form. (a)
- A description of the circumstances under which the loss or theft occurred. (b)
- A statement of disposition or probable disposition of the radioactive material involved. (c)
- Radiation exposures to individuals, circumstances under which the exposures occurred, and the possible total effective dose equivalent (TEDE) to persons in unrestricted areas. (d)
- Actions that were taken or will be taken to recover the material. (e)
- Procedures or measures that were adopted or will be adopted to prevent a recurrence of the loss or theft of radioactive material. (f)

Subsequent to filing the written report, the reporting office also shall report to the Director, NMSS, and the appropriate Deputy Executive Director for Operations any substantive additional information on the loss or theft that becomes available within 30 days of learning this information. (3)

# Notification of Incidents (C)

**Immediate Notification** (1)

Headquarters and regional offices shall immediately notify the NRC Operations Center in person or by telephone after discovering any incident involving radioactive material under NRC control that may have caused—

- An individual to receive any of the following: (a)
  - A total effective dose equivalent of 25 rem (0.25 Sv) or more (i)
  - An eye dose equivalent of 75 rem (0.75 Sv) or more (ii)
  - A shallow dose equivalent to the skin or extremities of 250 rads (2.5 Gy) or more (iii)
- The release of radioactive material inside or outside a restricted area that could cause an individual present for 24 hours to receive an intake five times the annual limit on intake. **Note:** The provisions of this paragraph do not apply to locations in which personnel are not normally stationed during routine operations, such as hotcells or process enclosures. (b)

**Twenty-four Hour Notification** (2)

Headquarters and regional offices shall notify the NRC Operations Center in person or by telephone within 24 hours of discovering any of the following events involving radioactive material under NRC control:

- An event that may have caused an individual to receive any of the following in a period of 24 hours: (a)
  - A total effective dose equivalent of 5 rem (0.05 Sv) or more (i)
  - An eye dose equivalent of 15 rem (0.15 Sv) or more (ii)
  - A shallow dose equivalent to the skin or extremities of 50 rem (0.5 Sv) or more (iii)
- An event that may have caused a release of radioactive material inside or outside a restricted area that could cause an individual present for 24 hours to receive an intake in excess of one annual

## Notification of Incidents (C) (continued)

Twenty-four Hour Notification (2) (continued)

limit on intake (ALI). **Note:** The provisions of this paragraph do not apply to locations in which personnel are not normally stationed during routine operations, such as hotcells or process enclosures. (b)

- An unplanned contamination event that requires access to the contaminated area, by workers or the public, to be restricted for more than 24 hours by imposing additional radiological controls or prohibiting entry into the area. (c)
- An event that requires unplanned medical treatment at a medical facility of an individual with spreadable radioactive contamination on the individual's clothing or body. (d)
- An unplanned fire or explosion that damages radioactive material, or any device, container, or equipment containing radioactive material when—(e)
  - The quantity of material involved is greater than five times the lowest ALI specified for the material in 10 CFR 20.1001–2402, Appendix B (i)
  - The damage affects the integrity of the radioactive material or its container (ii)

## Reports of Overexposures and Excessive Levels and Concentrations of Radioactivity (D)

In addition to any notification required by Section (C) of this part, headquarters and regional offices shall submit a written report to the Director, NMSS, and the appropriate Deputy Executive Director within 30 days of discovering any of the following events: (1)

- Each exposure of an individual to radiation or radioactive material in excess of the applicable limits specified in Part II of this handbook (a)
- Any incident for which notification is required by Section (C) of this part (b)

## Reports of Overexposures and Excessive Levels and Concentrations of Radioactivity (D) (continued)

- Levels of radiation or concentrations of radioactive material in—(c)
  - A restricted area in excess of any applicable limit specified in 10 CFR Part 20 (i)
  - An unrestricted area in excess of 10 times any applicable limit specified in 10 CFR Part 20, whether or not these levels cause an overexposure (ii)

Each written report required by this section must describe the extent of exposure of individuals to radiation or to radioactive material, including, as appropriate—(2)

- Estimates of each individual's dose (a)
- The levels of radiation and concentrations of radioactive material involved (b)
- The cause of the event (c)
- The corrective steps taken or planned (d)

Each written report required by this section shall include, in a separate and detachable part, the name, social security number, and date of birth for each individual exposed. If an embryo or a fetus is involved, the identifiers should be those of the declared pregnant woman. (3)

## Reports of Planned Special Exposures (E)

Headquarters and regional offices shall submit a written report to the Director, NMSS, and the appropriate Deputy Executive Director within 30 days of any planned special exposure informing them that a planned special exposure was conducted, indicating the date the planned special exposure occurred, and providing the information required by Section (A)(5)(a) of this part.

# Notifications and Reports to Individuals (F)

Radiation exposure data for an individual and the results of any measurements, analyses, and calculations of radioactive material deposited or retained in the body of an individual will be reported to the individual on at least an annual basis or as otherwise specified in this part. The information reported will include data and results obtained pursuant to the provisions of this handbook. Each notification and report will be in writing and will include appropriate identifying data, such as the name of the individual, the individual's social security number, the individual's exposure information, and will contain the following statement: (1)

> This report is furnished to you under the provisions of Management Directive 10.131. You should preserve this report for further reference.

At the employee's request, the NRC shall advise the employee of any exposure to radiation or radioactive material as shown in records maintained pursuant to this handbook. (2)

At the request of an individual formerly engaged in activities involving exposure to radiation while employed by the NRC, the individual will be furnished a report of exposure to radiation or radioactive material. This report—(3)

- Will be furnished within 30 days from the time the request is made or within 30 days after the exposure has been determined, whichever is later (a)
- Will cover, for the period of time specified in the request, each year in which the individual's activities involved exposure to radiation or radioactive material associated with NRC activities (b)
- Will include the dates and office assignments for the individual who participated during this period (c)

When a report of an overexposure to radiation or radioactive material is required under Section (D) of this part, the individual shall be notified. The NRC shall transmit this notice before or at the same time as the report. (4)

## Notifications and Reports to Individuals (F) (continued)

At the request of an individual who is terminating NRC employment that involved exposure to radiation or radioactive materials, the NRC shall provide, at termination, a written report regarding the radiation dose received by that individual during their employment with the NRC. If the most recent individual monitoring results are not available at that time, a written estimate will be provided, together with a clear indication that it is an estimate. (5)

# Part VI
# Guidance for Emergency Exposure Control During Rescue and Recovery Activities

## Purpose (A)

The emergency action guidance contained in this part provides instructions and background information for use by NRC employees in determining appropriate actions for the rescue and recovery of persons and the protection of health and property during an emergency.

## General Considerations (B)

Rescue and recovery operations should always be performed so as to minimize the risk of injury to those persons involved in such operations, to limit radiation exposures consistent with the saving of human life and the recovery of deceased victims, and to protect the health of the public and preserve property. Performing rescue and recovery operations requires the prompt assessment of hazards that may be involved with these operations and the determination of alternate methods of accomplishing them. Sound judgment, flexible plans, and adequate and versatile resources are crucial to the success of rescue and recovery operations. (1)

To avoid undue restrictions on actions that may be necessary during rescue and recovery operations, these instructions include flexibility in the establishment of exposure limits by responsible officials. The determination of exposures appropriate to rescue and recovery operations is the responsibility of the official in charge of these operations. (2)

The official in charge of the rescue or recovery activity shall determine the suitability of any proposed action involving radiation exposure by weighing the risks of radiation exposure, actual or potential, against

## General Considerations (B) (continued)

the benefits to be gained by the proposed action. The magnitude of the expected individual and collective doses and the biological consequences related to these doses are the essential elements to be evaluated in making a risk determination. (3)

The following tables list some of the biological effects associated with various radiation doses: (4)

### Table VI–1 Early Biological Effects of Acute Radiation Exposures*

| Radiation Dose | Acute Effect |
|---|---|
| 10 rads, whole body | Elevated number of chromosome aberrations; no clinical injury or symptoms |
| 25-50 rads, whole body | Changes in number of blood cells |
| 150 rads, whole body | Mild radiation sickness—nausea, vomiting, and fatigue are possible |
| 300 rads, whole body | Probably will result in death for 50% of untreated population |
| 500 rads, whole body | Probably will result in death of 50% of exposed population with good supportive medical treatment |
| 1000-2000 rads, whole body | Death in 3-10 days from intestinal tract damage |
| 10,000 rads or more, whole body | Death within 48 hours as a result of central nervous system damage |
| 200-400 rads, locally to eye | Cataract probable in 50% of exposed population |
| 500-700 rads to skin (areas larger than 50 square cm) | Erythema |
| 1000-2000 rads to skin (areas and blistering larger than 50 square cm) | Erythema and blistering |

*NUREG/CR-4214, "Health Effects Models for Nuclear Power Plant Accident Consequence Analysis," Revision I, Part II, Addendum 1, August 1991, and EPA 400-R-92-001, "Manual of Protective Action Guides and Protective Actions for Nuclear Incidents," May 1992.

## General Considerations (B) (continued)

**Table VI–2 Health Effects Associated With Whole-Body Absorbed Doses Received Within a Few Hours***

| Whole-Body Absorbed Dose (rads) | Early Fatalities (percent) | Whole-Body Absorbed Dose (rads) | Prodromal Effects** (percent affected) |
|---|---|---|---|
| 140 | 5 | 50 | 2 |
| 200 | 15 | 100 | 15 |
| 300 | 50 | 150 | 50 |
| 400 | 85 | 200 | 85 |
| 460 | 95 | 250 | 98 |

*EPA 400-R-92-001, "Manual of Protective Action Guides and Protective Actions for Nuclear Incidents," May 1992.
**Warning symptoms (e.g., nausea, fatigue, and so on) of more serious health effects associated with large doses of radiation.

**Table VI–3 Approximate Cancer Risk to Average Individuals From 25 Rem Effective Dose Equivalent Delivered Promptly***

| Age at Exposure (years) | Approximate Risk of Premature Death (deaths per 1,000 persons exposed) | Average Years of Life Lost If Premature Death Occurs (years) |
|---|---|---|
| 20 to 30 | 9.1 | 24 |
| 30 to 40 | 7.2 | 19 |
| 40 to 50 | 5.3 | 15 |
| 50 to 60 | 3.5 | 11 |

*EPA 400-R-92-001, "Manual of Protective Action Guides and Protective Actions for Nuclear Incidents," May 1992.

In these instructions, the criteria for accident situations that involve saving lives and valuable property and protecting the health of the public differ from the criteria for recovering deceased victims. In the latter instance, the amount of expected dose received by individual participants should be limited to occupational exposure limits. (5)

## General Considerations (B) (continued)

The use of potassium iodide will be considered to minimize thyroid doses. Scientific data shows that to maximize its benefit, potassium iodide must be taken several hours before the planned exposure. (6)

## Emergency Situations (C)

Specific dose criteria and judgment factors are specified for three categories of actions: saving human life, recovering deceased victims, and protecting health and property. When emergency actions are likely to affect an employee or facility of an NRC licensee, emergency actions will be coordinated with those specified in the licensee's emergency plans or other existing plans to avoid any appreciable differences between dose criteria and judgment factors used by the NRC and the licensee. These actions will not be limited to the rescue of NRC employees and NRC contractors alone but will also apply to employees of licensees, contractors, and visitors. Guidance on dose limits for workers performing emergency services extracted from the Environmental Protection Agency (EPA) "Manual of Protective Action Guides and Protective Actions for Nuclear Incidents" is provided in Table VI–4 of this part.

**Saving Human Life** (1)

When a reasonable expectation exists that an individual is alive within the affected areas during an emergency and is in need of rescue or medical treatment, the course of action to be pursued should be determined by the official onsite having responsibility for emergency actions. (a)

The official on site having responsibility for emergency action shall determine the amount of exposure suitable for this type of action. The dose expected in performing the action must be weighed in terms of the effects of acute external whole-body exposure and the entry of radioactive material into the body. In accordance with EPA's protective action guide, the official may permit volunteers to receive a dose up to 25 rem total effective dose equivalent (TEDE) **without** informed consent for emergency lifesaving activities. Any lifesaving action that may involve a dose greater than 25 rem TEDE, or other substantial personal risk, must be performed by volunteers advised of the known or estimated risk before participation. Preference will be given to volunteers who meet the following criteria: (b)

# Emergency Situations (C) (continued)

**Saving Human Life** (1) (continued)

- Over 45 years of age (i)
- Physically fit and in good physical condition as determined by a recent physical examination, for example, no adverse heart condition (ii)

In establishing exposure limits for the rescue operation, the official shall keep in mind that the accuracy of the prediction of radiation injury cannot be any better than the accuracy of the dose estimate. Therefore, consideration will be given to limits of error associated with the specific instruments and techniques used to estimate the dose. This process is especially crucial when the estimated doses are greater than 25 rem. The possibility of reducing estimated doses through appropriate mechanisms, such as the use of protective equipment, remote manipulation equipment, the use of potassium iodide, or similar means, will be considered. (c)

When making a decision to perform the action, the risk to rescue personnel will be weighed against the probability of the success of the rescue action. (d)

**Protecting Health and Property** (2)

When the risk (probability and severity) of the radiation hazard either bears significantly on the state of health of people or may result in undue loss of property and requires immediate remedial action, the following criteria apply:

- When the official in charge of emergency action onsite deems it essential to reduce a potential hazard or to prevent a substantial loss of property and determines that occupational dose limits applicable to routine operations may be exceeded, an emergency exposure consistent with guidance on dose limits specified in Table VI–4 may be authorized. However, planned special exposures are encouraged if there is time (see Part II of this handbook). (a)
- When the potential risk of radiation hazard following a nuclear incident jeopardizes life or poses severe adverse effects on the public health, the criteria specified in Section (C)(1) of this part for the saving of human life apply. (b)

**Recovering Deceased Victims** (3)

Accidents that involve recovering deceased victims require criteria different from those for saving lives. Because the element of time is no

# Emergency Situations (C) (continued)

**Recovering Deceased Victims** (3) (continued)

longer a critical factor, more time may be allowed for the planning of the recovery operation. The amount of radiation exposure received by persons engaged in these recovery operations should be within existing occupational exposure limits. (See Part II of this handbook.) (a)

When bodies are located in areas that are inaccessible because of high radiation fields and the recovery mission would result in exposure in excess of occupational exposure limits, remote recovery devices will be used to the extent practical to retrieve the bodies. (b)

In special circumstances, such as the entry of emergency workers into high radiation fields to recover bodies, the individual in charge of the recovery mission may determine that it is necessary to exceed the occupational exposure limits applicable to routine operations. In this case, a planned special exposure may be authorized for participating individuals. (See Part II of this handbook.) (c)

**Table VI–4 Guidance on Dose Limits for Workers Performing Emergency Services***

| Dose Limit (rem) | Activity | Condition |
|---|---|---|
| 5 | All | |
| 10 | Protecting valuable property | Lower dose not practicable |
| 25 | Lifesaving or protecting large populations | Lower dose not practicable |
| >25 | Lifesaving or protecting large populations | Only on a voluntary basis to persons fully aware of the risks involved |

*EPA 400-R-92-001, "Manual of Protective Action Guides and Protective Actions for Nuclear Incidents," May 1992.
NOTE: "Dose limit" refers to the sum of external effective dose equivalent and committed effective dose equivalent to nonpregnant adults from exposure and intake during an emergency situation. Workers performing services during emergencies should limit the dose to the lens of the eye to three times the listed value and doses to any other organ, including skin and body extremities, to 10 times the listed values.

# Implementation (D)

Each regional office must establish a plan to implement this guidance for emergency response during rescue and recovery activities. This plan will—

- Designate an individual by position or title who has authority to authorize emergency workers to receive doses in excess of limits specified in this handbook. The regional administrator in each region should be designated as the lead person in charge of emergency action for the region. (1)
- Provide for periodic training, including written examinations, to all appropriate regional personnel on the emergency exposure procedures to be followed during rescue and recovery activities. (2)

# Exhibit 1

# NRC Form 525, "Request for and Authorization of Release of Dosimetry Records"

NRC FORM 525 (11-91) — U.S. NUCLEAR REGULATORY COMMISSION

## REQUEST FOR AND AUTHORIZATION OF RELEASE OF DOSIMETRY RECORDS

**REQUEST TO**

| NAME OF ORGANIZATION | NAME OF FACILITY |
|---|---|
| | |

ADDRESS

**REQUEST FROM**

| NAME OF NRC EMPLOYEE | SOCIAL SECURITY NUMBER |
|---|---|
| | |

**EXPOSURE RECORD PERIOD**

| BEGINNING | | ENDING | |
|---|---|---|---|
| | | | |

I request, pursuant to 10 CFR 19.13, that a copy of my exposure records required by 10 CFR 20.401(a) and (c) for the period listed here be provided to:

RADIATION SAFETY OFFICER
MAIL STOP _____
U. S. NUCLEAR REGULATORY COMMISSION
WASHINGTON, DC 20555

| SIGNATURE - NRC EMPLOYEE | DATE |
|---|---|
| | |

NRC FORM 525 (11-91)

# Exhibit 1 (continued)

## PRIVACY ACT STATEMENT

Pursuant to 5 U.S.C. 552a(e)(3), enacted into law by Section 3 of the Privacy Act of 1974 (Public Law 93-579), the following statement is furnished to individuals who supply information to the Nuclear Regulatory Commission on NRC Form 525. This information is maintained in a system of records designated as NRC-11 and described at 55 Federal Register 33975 (August 20, 1990).

1. AUTHORITY: 42 U.S.C. 2073, 2093, 2095, 2111, 2133, 2134, and 2201(o) (1988). The authority for soliciting the social security number is Executive Order 9397, dated November 22, 1943.

2. PRINCIPAL PURPOSE(S): The information is used by the NRC in its evaluation of the risk of radiation exposure associated with NRC activities and in exercising its statutory responsibility to monitor and regulate the safety and health practices of its employees. The data permits maintaining a complete record of radiation exposure received while performing NRC business. Data on your exposure to radiation is available to you upon your request.

3. ROUTINE USES: The information may be used to provide data to other Federal and State agencies involved in monitoring and/or evaluating radiation exposure received by NRC employees employed as radiation workers on a permanent or temporary basis and exposure received by monitored visitors. This information may also be disclosed to an appropriate Federal, State, or local agency in the event the information indicates a violation or potential violation of law and in the course of an administrative or judicial proceeding.

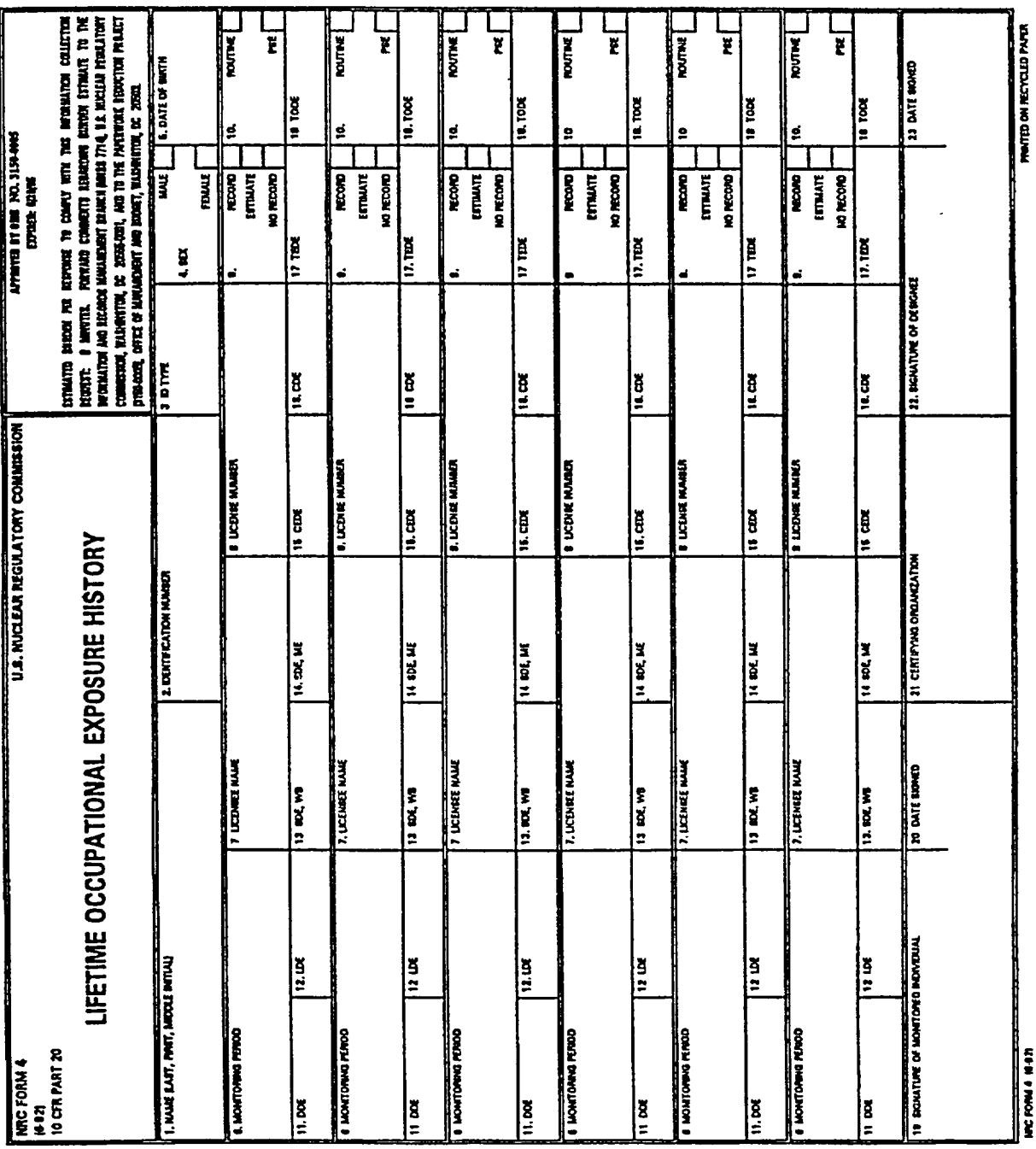
4. WHETHER DISCLOSURE IS MANDATORY OR VOLUNTARY AND EFFECT ON INDIVIDUAL OF NOT PROVIDING INFORMATION: It is voluntary that you furnish the requested information, including social security number; however, the licensee must provide radiation exposure data upon your request as required under 10 CFR 19.13 and in accordance with the requirements imposed under 10 CFR 20.401 to keep records of radiation exposure of all individuals entering a restricted area. Failure to provide the social security number to the licensee may result in the licensee being unable to accurately identify the individual requesting radiation exposure information. The social security number is used to ensure that NRC and the licensee have an accurate identifier not subject to the coincidence of similar names or birthdates among the large number of persons on whom data is maintained.

5. SYSTEM MANAGER(S) AND ADDRESS:

DIRECTOR
OFFICE OF PERSONNEL
U. S. NUCLEAR REGULATORY COMMISSION
WASHINGTON DC 20555

# Exhibit 2

## NRC Form 4, "Lifetime Occupational Exposure History"



PAGE ____ OF ____

NRC FORM 4
(6-92)
10 CFR PART 20

U.S. NUCLEAR REGULATORY COMMISSION

LIFETIME OCCUPATIONAL EXPOSURE HISTORY

APPROVED BY OMB NO. 3150-0005
EXPIRES: 6/30/96

ESTIMATED BURDEN PER RESPONSE TO COMPLY WITH THIS INFORMATION COLLECTION REQUEST: 9 MINUTES. FORWARD COMMENTS REGARDING BURDEN ESTIMATE TO THE INFORMATION AND RECORDS MANAGEMENT BRANCH (MNBB 7714), U.S. NUCLEAR REGULATORY COMMISSION, WASHINGTON, DC 20555-0001, AND TO THE PAPERWORK REDUCTION PROJECT (3150-0005), OFFICE OF MANAGEMENT AND BUDGET, WASHINGTON, DC 20503.

1. NAME (LAST, FIRST, MIDDLE INITIAL)

2. IDENTIFICATION NUMBER

3 ID TYPE

4. SEX: MALE / FEMALE

5. DATE OF BIRTH

6. MONITORING PERIOD

7. LICENSEE NAME

8. LICENSE NUMBER

9. 10. RECORD / ESTIMATE / NO RECORD — ROUTINE / PRE

11. DOE

12. LDE

13. EDE, WB

14. EDE, ME

15. CEDE

16. CDE

17. TEDE

18. TODE

19. SIGNATURE OF MONITORED INDIVIDUAL

20. DATE SIGNED

21. CERTIFYING ORGANIZATION

22. SIGNATURE OF OFFICIAL

23. DATE SIGNED

NRC FORM 4 (6-92)

PRINTED ON RECYCLED PAPER

# Exhibit 2 (continued)

## INSTRUCTIONS AND ADDITIONAL INFORMATION PERTINENT TO THE COMPLETION OF NRC FORM 4

*(All doses should be stated in rems)*

1. Type or print the full name of the monitored individual in the order of last name (include "Jr," "Sr," "III," etc.), first name, middle initial (if applicable).
2. Enter the individual's identification number, including punctuation. This number should be the 9-digit social security number if at all possible. If the individual has no social security number, enter the number from another official identification such as a passport or work permit.
3. Enter the code for the type of identification used as shown below:

| CODE | ID TYPE |
|---|---|
| SSN | U.S. Social Security Number |
| PPN | Passport Number |
| CSI | Canadian Social Insurance Number |
| WPN | Work Permit Number |
| IND | INDEX Identification Number |
| OTH | Other |

4. Check the box that denotes the sex of the individual being monitored.
5. Enter the date of birth of the individual being monitored in the format MM/DD/YY.
6. Enter the monitoring period for which this report is filed. The format should be MM/DD/YY - MM/DD/YY.
7. Enter the name of the licensee or facility not licensed by NRC that provided monitoring.
8. Enter the NRC license number or numbers
9. Place an "X" in Record, Estimate, or No Record. Choose "Record" if the dose data listed represent a final determination of the dose received to the best of the licensee's knowledge. Choose "Estimate" only if the listed dose data are preliminary and will be superseded by a final determination resulting in a subsequent report. An example of such an instance would be dose data based on self-reading dosimeter results and the licensee intends to assign the record dose on the basis of TLD results that are not yet available.
10. Place an "X" in either Routine or PSE. Choose "Routine" if the data represent the results of monitoring for routine exposures. Choose "PSE" if the listed dose data represents the results of monitoring of planned special exposures received during the monitoring period. If more than one PSE was received in a single year, the licensee should sum them and report the total of all PSEs.
11. Enter the deep dose equivalent (DDE) to the whole body.
12. Enter the eye dose equivalent (LDE) recorded for the lens of the eye.
13. Enter the shallow dose equivalent recorded for the skin of the whole body (SDE,WB).
14. Enter the shallow dose equivalent recorded for the skin of the extremity receiving the maximum dose (SDE,ME).
15. Enter the committed effective dose equivalent (CEDE)
16. Enter the committed dose equivalent (CDE) recorded for the maximally exposed organ.
17. Enter the total effective dose equivalent (TEDE). The TEDE is the sum of Items 11 and 15.
18. Enter the total organ dose equivalent (TODE) for the maximally exposed organ. The TODE is the sum of Items 11 and 16.
19. Signature of the monitored individual. The signature of the monitored individual on this form indicates that the information contained on the form is complete and correct to the best of his or her knowledge.
20. Enter the date this form was signed by the monitored individual.
21. [OPTIONAL] Enter the name of the licensee or facility not licensed by NRC, providing monitoring for exposure to radiation (such as a DOE facility) or the employer if the individual is not employed by the licensee and the employer chooses to maintain exposure records for its employees.
22. [OPTIONAL] Signature of the person designated to represent the licensee or employer entered in Item 21. The licensee or employer who chooses to countersign the form should have on file documentation of all the information on the NRC Form 4 being signed.
23. [OPTIONAL] Enter the date the form was signed by the designated representative.

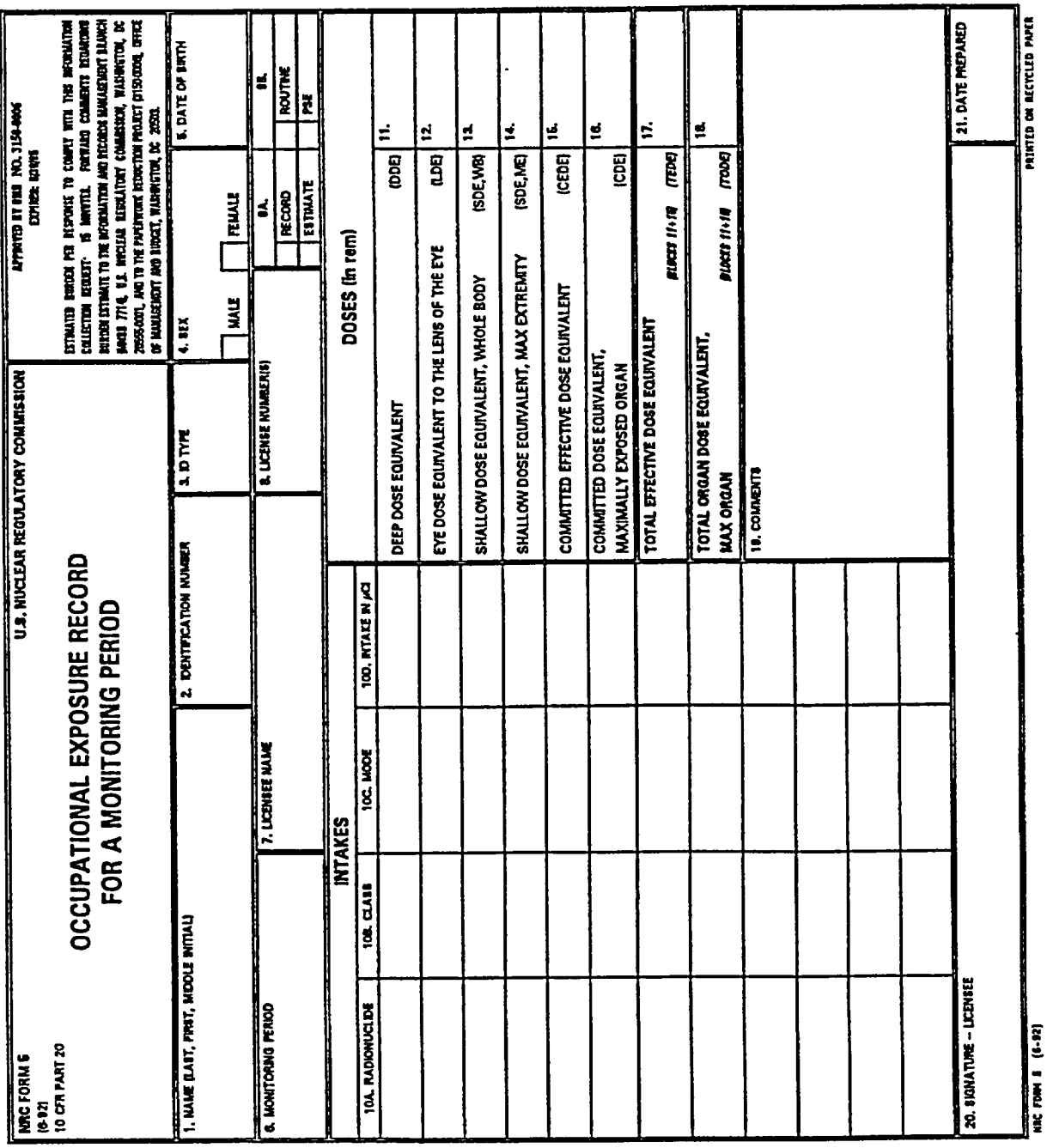
## PRIVACY ACT STATEMENT

Pursuant TO 5 U.S.C. 552a(e)(3), enacted into law by Section 3 of the Privacy Act of 1974 (Public Law 93-579), the following statement is furnished to individuals who supply information to the U.S. Nuclear Regulatory Commission on NRC Form 4. This information is maintained in a system of records designated as NRC 27 and described at 55 Federal Register 33984 (August 20, 1990), or the most recent Federal Register publication of the Nuclear Regulatory Commission's "Republication of Systems of Records Notices" that is available at the NRC Public Document Room, Gelman Building, Lower Level, 2120 L Street NW, Washington, D.C.

1. AUTHORITY: Sections 53, 63, 65, 81, 103, 104, 161(b), and 161(o) of the Atomic Energy Act of 1954, as amended (42 U.S.C. 2073, 2093, 2095, 2111, 2133, 2134, 2201(b), and 2201(o)). The authority for soliciting the social security number is 10 CFR Part 20.
2. PRINCIPAL PURPOSE(S): The information is used by the NRC in its evaluation of the risk of radiation exposure associated with the licensed activity and in exercising its statutory responsibility to monitor and regulate the safety and health practices of its licensees. The data permits a meaningful comparison of both current and long-term exposure experience among types of licensees and among licensees within each type. Data on your exposure to radiation is available to you upon your request.
3. ROUTINE USE(S): The information may be used to provide data to other Federal and State agencies involved in monitoring and/or evaluating radiation exposure received by individuals employed as radiation workers on a permanent or temporary basis and exposure received by monitored visitors. The information may also be disclosed to an appropriate Federal, State, or local agency in the event the information indicates a violation or potential violation of law and in the course of an administrative or judicial proceeding
4. WHETHER DISCLOSURE IS MANDATORY OR VOLUNTARY AND EFFECT ON INDIVIDUAL OF NOT PROVIDING INFORMATION: It is voluntary that you furnish the requested information, including social security number; however, the licensee must complete NRC Form 5 on each individual for whom personnel monitoring is required under 10 CFR 20.2106. Failure to do so may subject the licensee to enforcement action in accordance with 10 CFR 20.2401. The social security number is used to assure that NRC has an accurate identifier not subject to the coincidence of similar names or birthdates among the large number of persons on whom data is maintained.
5. SYSTEM MANAGER(S) AND ADDRESS:
   REIRS Project Manager
   Office of Nuclear Regulatory Research
   U.S. Nuclear Regulatory Commission
   Washington, DC 20555-0001

# Exhibit 3

## NRC Form 5, "Occupational Exposure Record for a Monitoring Period"



PAGE ____ OF ____

NRC FORM 5
(6-92)
10 CFR PART 20

U.S. NUCLEAR REGULATORY COMMISSION

OCCUPATIONAL EXPOSURE RECORD
FOR A MONITORING PERIOD

APPROVED BY OMB NO. 3150-0006
EXPIRES: 6/30/95

ESTIMATED BURDEN PER RESPONSE TO COMPLY WITH THIS INFORMATION COLLECTION REQUEST: 15 MINUTES. FORWARD COMMENTS REGARDING BURDEN ESTIMATE TO THE INFORMATION AND RECORDS MANAGEMENT BRANCH (MNBB 7714), U.S. NUCLEAR REGULATORY COMMISSION, WASHINGTON, DC 20555-0001, AND TO THE PAPERWORK REDUCTION PROJECT (3150-0006), OFFICE OF MANAGEMENT AND BUDGET, WASHINGTON, DC 20503.

1. NAME (LAST, FIRST, MIDDLE INITIAL)
2. IDENTIFICATION NUMBER
3. ID TYPE
4. SEX — MALE / FEMALE
5. DATE OF BIRTH
6. MONITORING PERIOD
7. LICENSEE NAME
8. LICENSE NUMBER(S)
8A. RECORD / ESTIMATE
8B. ROUTINE / PAE

INTAKES

| 10A. RADIONUCLIDE | 10B. CLASS | 10C. MODE | 10D. INTAKE IN µCi |
|---|---|---|---|
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |

DOSES (in rem)

| | | |
|---|---|---|
| DEEP DOSE EQUIVALENT | (DDE) | 11. |
| EYE DOSE EQUIVALENT TO THE LENS OF THE EYE | (LDE) | 12. |
| SHALLOW DOSE EQUIVALENT, WHOLE BODY | (SDE,WB) | 13. |
| SHALLOW DOSE EQUIVALENT, MAX EXTREMITY | (SDE,ME) | 14. |
| COMMITTED EFFECTIVE DOSE EQUIVALENT | (CEDE) | 15. |
| COMMITTED DOSE EQUIVALENT, MAXIMALLY EXPOSED ORGAN | (CDE) | 16. |
| TOTAL EFFECTIVE DOSE EQUIVALENT (BLOCKS 11+12) | (TEDE) | 17. |
| TOTAL ORGAN DOSE EQUIVALENT, MAX ORGAN (BLOCKS 11+12) | (TODE) | 18. |

18. COMMENTS

20. SIGNATURE – LICENSEE

21. DATE PREPARED

NRC FORM 5 (6-92)

PRINTED ON RECYCLED PAPER

# Exhibit 3 (continued)

**INSTRUCTIONS AND ADDITIONAL INFORMATION PERTINENT TO THE COMPLETION OF NRC FORM 5**
***(All doses should be stated in rems)***

1. Type or print the full name of the monitored individual in the order of last name (include "Jr," "II," etc.), first name, middle initial (if applicable).

2. Enter the individual's identification number, including punctuation. This number should be the 9-digit social security number if at all possible. If the individual has no social security number, enter the number from another official identification such as a passport or work permit.

3. Enter the code for the type of identification used as shown below:

| CODE | ID TYPE |
|---|---|
| SSN | U.S. Social Security Number |
| PPN | Passport Number |
| CSI | Canadian Social Insurance Number |
| WPN | Work Permit Number |
| IND | INDEX Identification Number |
| OTH | Other |

4. Check the box that denotes the sex of the individual being monitored.

5. Enter the date of birth of the individual being monitored in the format MM/DD/YY.

6. Enter the monitoring period for which this report is filed. The format should be MM/DD/YY - MM/DD/YY.

7. Enter the name of the licensee.

8. Enter the NRC license number or numbers.

8A. Place an "X" in Record, Estimate, or No Record. Choose "Record" if the dose data listed represent a final determination of the dose received to the best of the licensee's knowledge. Choose "Estimate" only if the listed dose data are preliminary and will be superseded by a final determination resulting in a subsequent report. An example of such an instance would be dose data based on self-reading dosimeter results and the licensee intends to assign the record dose on the basis of TLD results that are not yet available.

8B. Place an "X" in either Routine or PSE. Choose "Routine" if the data represent the results of monitoring for routine exposures. Choose "PSE" if the listed dose data represents the results of monitoring of planned special exposures received during the monitoring period. If more than one PSE was received in a single year, the licensee should sum them and report the total of all PSEs.

10A. Enter the symbol for each radionuclide that resulted in an internal exposure recorded for the individual, using the format "Xx-###x." for instance, Cs-137 or Tc-99m.

10B. Enter the lung clearance class as listed in Appendix B to 10 CFR Part 20.1001-2401 (D, W, Y, V, or O for other) for all intakes by inhalation.

10C. Enter the mode of intake. For inhalation, enter "H." For absorption through the skin, enter "S." For oral ingestion, enter "G." For injection, enter "J."

10D. Enter the intake of each radionuclide in μCi.

11. Enter the deep dose equivalent (DDE) to the whole body.

12. Enter the eye dose equivalent (LDE) recorded for the lens of the eye.

13. Enter the shallow dose equivalent recorded for the skin of the whole body (SDE_WB).

14. Enter the shallow dose equivalent recorded for the skin of the extremity receiving the maximum dose (SDE_ME).

15. Enter the committed effective dose equivalent (CEDE).

16. Enter the committed dose equivalent (CDE) recorded for the maximally exposed organ.

17. Enter the total effective dose equivalent (TEDE). The TEDE is the sum of items 11 and 15.

18. Enter the total organ dose equivalent (TODE) for the maximally exposed organ. The TODE is the sum of items 11 and 16.

19. Signature of the person designated to represent the licensee.

20. Enter the date this form was prepared.

21. COMMENTS.
In the space provided, enter additional information that might be needed to determine compliance with limits. An example might be to enter the note that the SDE_ME was the result of exposure from a discrete hot particle. Another possibility would be to indicate that an overexposed report has been sent to NRC in reference to the exposure report.

**PRIVACY ACT STATEMENT**

Pursuant TO 5 U S C. 552a(e)(3), enacted into law by Section 3 of the Privacy Act of 1974 (Public Law 93-579), the following statement is furnished to individuals who supply information to the U S. Nuclear Regulatory Commission on NRC Form 5. The information is maintained in a system of records designated as NRC-27 and described at 55 Federal Register 33984 (August 20, 1990), or the most recent Federal Register publication of the Nuclear Regulatory Commission's "Republication of Systems of Records Notices" that is available at the NRC Public Document Room, Gelman Building, Lower Level, 2120 L Street NW, Washington, D.C.

1. AUTHORITY: Sections 53, 63, 65, 81, 103, 104, 161(b), and 161(o) of the Atomic Energy Act of 1954, as amended (42 U.S.C. 2073, 2093, 2095, 2111, 2133, 2134, 2201(b), and 2201(o)). The authority for soliciting the social security number is 10 CFR Part 20.

2. PRINCIPAL PURPOSE(S): The information is used by the NRC in its evaluation of the risk of radiation exposure associated with the licensed activity and in exercising its statutory responsibility to monitor and regulate the safety and health practices of its licensees. The data permits a meaningful comparison of both current and long-term exposure experience among types of licensee and among licensees within each type. Data on your exposure to radiation is available to you upon your request.

3. ROUTINE USE(S): The information may be used to provide data to other Federal and State agencies involved in monitoring and/or evaluating radiation exposure received by individuals employed as radiation workers on a permanent or temporary basis and exposure received by members of the public. The information may also be disclosed to an appropriate Federal, State, or local agency in the event the information indicates a violation or potential violation of law and in the course of an administrative or judicial proceeding.

4. WHETHER DISCLOSURE IS MANDATORY OR VOLUNTARY AND EFFECT ON INDIVIDUAL OF NOT PROVIDING INFORMATION: It is voluntary that you furnish the requested information, including social security number; however, the licensee must complete NRC Form 5 on each individual for whom personnel monitoring is required under 10 CFR 20.2106. Failure to do so may subject the licensee to enforcement action in accordance with 10 CFR 20.2401. The social security number is used to assure that NRC has an accurate identifier not subject to the coincidence of similar names or birthdates among the large number of persons on whom data is maintained.

5. SYSTEM MANAGER(S) AND ADDRESS:
REIRS Project Manager
Office of Nuclear Regulatory Research
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

# CHAPTER 4

# CONTROL OF RADIATION EXPOSURE

# 4.0 CONTROL OF RADIATION EXPOSURE

## 4.0.1 Purpose

Provide basic guidelines for participants in this course to maintain their radiation exposure as low as is reasonably achievable while at a nuclear power station or a fuel cycle facility.

## 4.0.2 Objectives

At the conclusion of this topic, course participants should be able to:

- Understand the need to keep total radiation exposure (sum of internal and external exposure) ALARA.
- Describe typical sources of radiation and contamination originating in a nuclear power station or fuel cycle facility,
- Describe three methods for reducing exposure from external sources,
- Explain the importance of good contamination control and list some methods of contamination control,
- Understand use of Radiation Work Permits (RWPs) , and
- Understand general radiation and contamination surveys.

## 4.0.3 Reference

- USNRC Regulatory Guide 8.8 - Information Relevant To Ensuring That Occupational Radiation Exposures At Nuclear Power Stations Will Be As Low As Is Reasonably Achievable

## 4.1 Sources of Radiation

### 4.1.1 Reactor Core and Vessel

#### 4.1.1.1 Fission Process

Very high levels of gamma and neutron radiation are generated by the fission process. The biological shields and shielding by components inside the reactor containment structure limit the radiation levels in routine work areas from the fission process to acceptable values (generally millirem per hour). When the reactor is shutdown, radiation from the fission process ceases.

#### 4.1.1.2 Fission Product Decay

The radioactive decay of fission products is a major source of radiation exposure to personnel inside containment when the reactor is shutdown and to personnel during reactor defueling.

### 4.1.2 Reactor Coolant

#### 4.1.2.1 Activation Products

The radioactive decay of activation products is the main source of radiation exposure to plant personnel. Radioactive activation products can be anywhere reactor coolant circulates, leaks, or is processed.

#### 4.1.2.2 Fission Products

Fission products may be in the reactor coolant in sufficient levels for exposure considerations if there are defective fuel elements.

### 4.1.3 Steam/Turbine/Condensate Systems

Any radiation source that is in the reactor coolant can be in the steam and condensate systems. In a pressurized water reactor (PWR) there must be a leakage pathway from the reactor or primary coolant system into the secondary or steam system for the radioactivity to reach the steam and condensate systems.

Boiling water reactor (BWR) coolant becomes the steam (no physical barrier separating the coolant and steam systems), so BWR plants have much higher radiation levels than PWRs near the steam systems due to the reactor coolant activation products in the BWR steam system. Nitrogen-16, a high energy gamma emitter, is a major source of exposure to BWR turbine floor operators.

### 4.1.4 Waste Treatment Systems

#### 4.1.4.1 Liquid Radwaste Treatment

The processing of liquid radioactivity involves processes that remove and concentrate activation and fission products through filtration, evaporation, ion-exchange, settling, and decay. Treatment components that should be avoided due to their very high external exposure potential are:

- Catch and Holding tanks,
- Ion exchangers,
- Evaporators, and
- Pipe systems ("chases").

#### 4.1.4.2 Solid Radwaste Treatment

Solid waste treatment usually involves the packaging, compacting, and handling of waste that is already in a solid form. Some of the solid waste (often that with the highest exposure levels) comes from liquid waste processing. Small radioactive components that could not be decontaminated, rags, and other radioactive or contaminated work debris are packaged as solid waste and are often classified as low level waste. Solid waste sources of significant exposure include:

- Resins, and
- Filters.

### 4.1.5 Spent Fuel Storage

#### 4.1.5.1 Pools

Fuel in spent fuel facilities is shielded by many feet of water, reducing the exposure level around the pool to very low levels.

Radioactive tools and reactor components may be lowered by line into the fuel pool for storage. Some of the items can cause very high exposures when removed from the pool or are near the water surface.

#### 4.1.5.2 Above Ground

Above ground storage in heavily shielded (concrete and steel) containers is being approved for the storage of older fuel. Radiation levels around accessible areas of these containers are relatively low.

### 4.1.6 Fuel Cycle Facilities

#### 4.1.6.1 Fuel Manufacturing

Uranium conversion and fuel fabrication facilities do not have significant external radiation hazards. Internal exposure from contamination is the primary radiation hazard at these facilities. However, external radiation levels may reach several hundred mrem/hr where U-238 decay daughters are concentrated and stored. Systems handling powdered uranium oxide and soluble forms of uranium (as in solvent extraction and dissolution systems) are major sources of contamination.

#### 4.1.6.2 Research and Development

Certain fuel cycle facilities test and analyze irradiated fuel and reactor components. Hot cells and other areas where irradiated materials are handled are major sources of external radiation exposure.

### 4.1.7 Examples of Other Sources

Some other sources of radiation are:

- Penetrations through walls and shields,
- Incore instruments and small reactor components,
- Transfer tubes/spent fuel movement,
- Calibration operations with radioactive sources, and
- Reactor coolant and waste processing samples.

## 4.2 Control of External Radiation Exposure

### 4.2.1 Time

Minimize the length of time your are exposed to radiation.

Calculate or know your "stay time" prior to entering radiation and high radiation areas.

### 4.2.2 Distance

Maximize the distance between you and the radiation source.

Radiation exposure varies inversely as the square of the distance from a small source. For example, if you double the distance between yourself and the source, your radiation exposure rate should decrease by a factor of four.

When the radiation source is large compared to your distance from it, the exposure rate is approximately inversely proportional. That is, if you double the distance, the exposure rate will decrease by about a factor of two.

### 4.2.3 Shielding

Keep as much shielding material between you and the radiation source as practicable. Use available shielding, such as installed equipment and walls whenever practicable.

Avoid being in "line of sight" of radioactive sources.

### 4.2.4 Contamination Control

Radioactive contamination is controlled to limit external exposure, prevent internal exposure, reduce the size of areas needing special controls, and to reduce radioactive waste processing.

One of the most important reasons for controlling contamination is to prevent or limit intake by personnel. Therefore, contamination control is discussed in detail in paragraph 4.3.2 below.

## 4.3 Control of Internal Radiation Exposure

### 4.3.1 Contamination Sources

Contamination is radioactive material in a location where it is unwanted and potentially hazardous to personnel. Most contamination at nuclear power plants is from activation products that leak from the reactor coolant system or are exposed during maintenance operations.

The primary sources of contamination at fuel cycle facilities are systems handling powdered uranium oxide and soluble forms of uranium (as in solvent extraction and dissolution systems).

#### 4.3.1.1 Contamination Forms

Solid contamination can exist as finely divided particles associated with dirt or other material. "Hot particles" or "fleas" are a special case involving very small, discrete, particles with relatively high activity. Solid contamination may settle or be on surfaces or it may be light enough to be kept airborne by air movement and/or electrostatic forces.

Liquid contamination can exist due to leaks from pipes, valves, or other pathways, including spills. Liquid contamination may dry and become solid or airborne contamination.

Gaseous contamination can result from gases produced in the reactor (fission products and dissociation) which are released via off-gas venting or from volatile material in liquids such as I-131 in reactor coolant.

#### 4.3.1.2 Categories and Detection

Personnel contamination, including skin contamination, is any form of radioactive contamination on personnel and is normally detected by survey with a sensitive Geiger Mueller (GM) detector such as a frisker, personnel monitor, or portal monitor.

Contamination in an area is generally categorized as:

- Fixed (or nonremovable),
- Loose (or removable), and
- Airborne.

Loose and airborne contamination pose the most serious health hazard because they can easily be inhaled, ingested, or contaminate personnel.

Loose and airborne contamination are detected by taking smears (wipes) of material in an area and by collecting air samples, respectively. The smears are usually counted with a sensitive GM detector in the laboratory. Some air samples require counting in the laboratory while some air samplers both collect and count the sample.

#### 4.3.1.3 Action Levels

Action levels for contamination depend on the type and locations of contamination and the normal use or functions of the area contaminated.

Typical action levels for contamination are:

| Type of contamination | Action Level |
|---|---|
| Personnel contamination | Any detectable (usually 50-100 cpm above background) |
| Removable beta-gamma | 1000 dpm/100cm$^2$ |
| Removable alpha | 20 dpm/100cm$^2$ |

### 4.3.2 Contamination Control

Control of loose contamination (including solid, liquid, and gaseous) reduces the risk of personnel contamination. Therefore, the primary reason for contamination control is to reduce the possibility of personnel contamination (external or internal). Examples of contamination controls are:

- Engineering controls such as controlled ventilation zones, HEPA filters, and catch trays under pumps and valves,
- Maintaining cleanliness throughout the facility with special attention paid to maintenance and work areas where contamination could spread,
- Conducting routine maintenance to stop leak paths,
- Posting and controlling contaminated areas,
- Minimizing the number of people that enter contaminated areas, and
- Require a whole body survey when leaving contaminated areas.

Controls an individual can use to reduce the risk of being contaminated are:

- Entering contaminated areas only when necessary and authorized,
- Using protective clothing properly,
- Using respirators or respiratory protection as prescribed and authorized,
- Avoiding higher contamination levels as much as practicable,
- Avoiding use of synthetic clothing,
- Avoiding floor drains, areas under open stairways, and contamination control boundaries/control points, and
- Completing a whole body survey when leaving contaminated areas.

### 4.3.3 Airborne Contamination Control (DAC-hours)

Control of personnel exposure to airborne radioactivity is accomplished by limiting the product of exposure time (hours) and the airborne concentration (DACs) as discussed in section 3.3.4.. Limiting the DAC-hours value can be accomplished by:

- Utilizing engineering controls , e.g., ventilation, air filtration, area decontamination, and containment devices; and practices discussed above to remove radioactivity from air or prevent the radioactivity from becoming airborne,
- Calculating your estimated DAC-hrs prior to entry into an airborne radioactivity area and then taking all reasonable action to minimize the actual value and to ensure that you do not exceed the permitted value, and
- As a last resort, using respirators as instructed by the facility health physicists, if you are respirator qualified.

The decision to use a respirator must take into account the effect on total exposure (consideration of increased external exposure due to increased time to perform the job), but may also have to be based on industrial safety concerns such as oxygen deficient atmospheres and heat stress. A respirator with a protection factor less than the peak ambient airborne radioactivity concentrations may be selected if done to keep total radiation exposure ALARA.

Licensees may control your exposure to airborne radioactive material by taking air samples and tracking DAC-hours or by using bioassay results (as discussed in Chapter 6) or any combination of these methods.

## 4.4 Exposure Monitoring

### 4.4.1 Thermo Luminescent Dosimeters (TLDs)

A TLD is normally required to be worn when entering a radiation area to monitor whole body exposure. Multiple TLDs and special TLDs may be required to monitor other whole body locations, extremity exposure and skin exposure. Periodic and special processing of the TLDs provides exposure data used to help control your exposure to prevent exceeding control or limits. Film badges may be used in place of TLDs. Both TLDs and film badges are discussed in greater detail in section 5.2.

### 4.4.2 Pocket Dosimeters

Pocket dosimeters are used for real-time monitoring of exposure. Self- reading dosimeters should be checked frequently while inside radiation areas. Pocket dosimeter results are used to update your exposure record and to control your exposure until your TLD is processed.

### 4.4.3 Digital and Alarming Dosimeters

Digital dosimeters, alarming dosimeters, "chirpers", and other audible dosimetry devices are used for monitoring and exposure control,

especially inside high radiation areas.

### 4.4.4 Other Monitoring

Exposure monitoring is also accomplished by frisking and other techniques used to identify and quantify exposure from contaminations such as using air sample results and exposure time to monitor the exposure to airborne radioactivity.

## 4.5 Radiation Work Permit (RWP)

An RWP is normally required for entry into a high or very high radiation area, contaminated area, or airborne radioactivity area. Some facilities have generic or "standing" RWPs that are required reading for everyone entering radiation controlled areas (usually required to be signed before dosimetry issue). Your inspection may require you to prepare or request a special RWP.

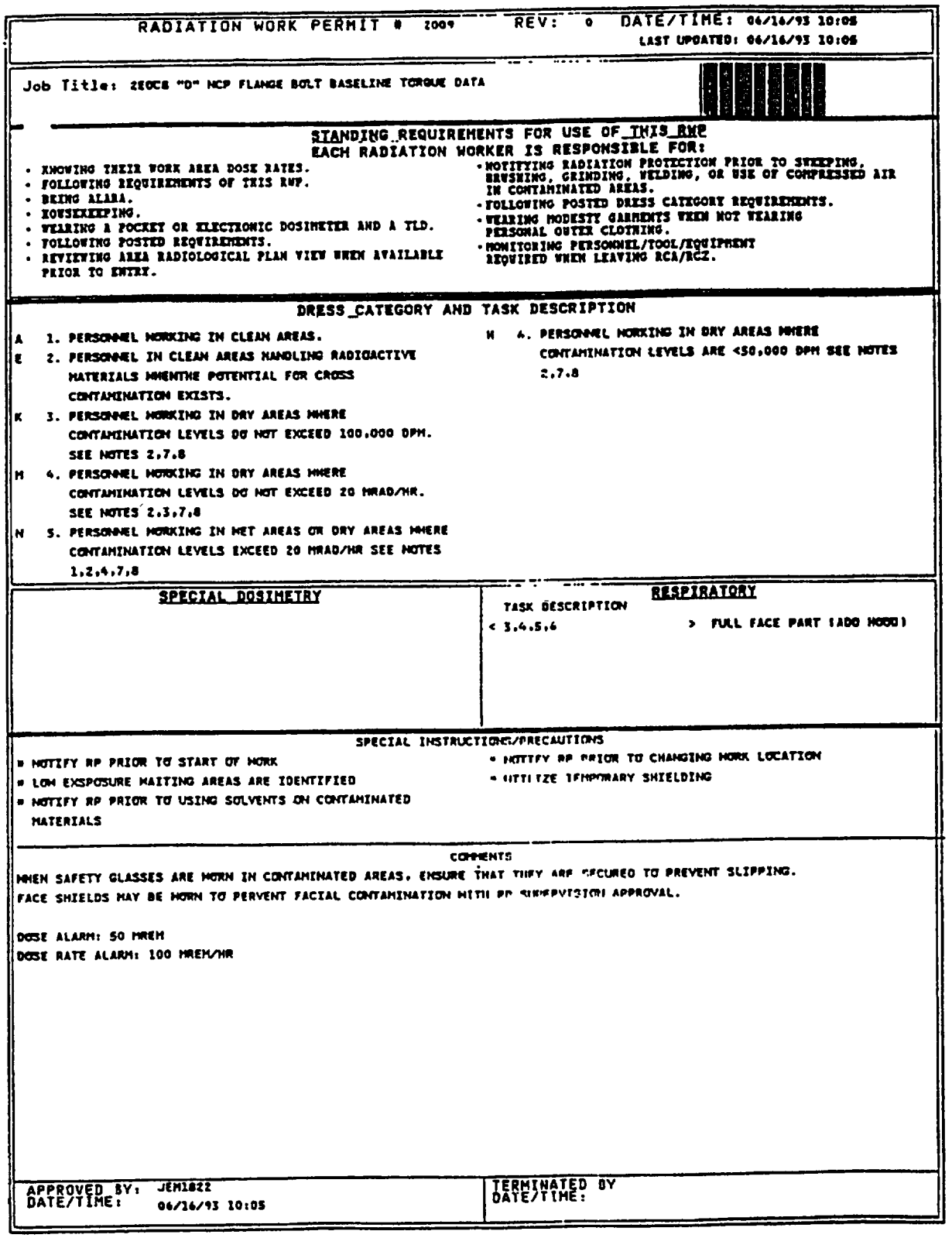
Read the RWP carefully; know and understand the requirements and your responsibilities. Your signature means you have read and understand all the stated requirements. See Figures 4-1 through 4-3 for RWP samples.

## 4.6 Surveys

You must be able to view and understand radiation surveys. If you have any uncertainty about the survey, ask health physics or your escort for clarification. Understanding a specific survey is usually a required part of an RWP. Note areas of highest levels and try to avoid them or note areas of lowest levels and try to stay in them. Survey records may be attached to the RWP, held at control points, or posted near area entrances. Some surveys examples are provided in Figures 4-4 through 4-6.

## 4.7 As Low As Reasonably Achievable (ALARA)

10 CFR Part 20.1101(b) requires licensees to have a program to maintain occupational radiation exposure ALARA. It is also your responsibility to take all reasonable actions to minimize your total radiation exposure (sum of internal and external) as an individual as well as the total radiation dose for a job (person-rem). This chapter has discussed many actions that can be utilized to help minimize your exposure and that of others working with you.



RADIATION WORK PERMIT # 2009 REV: 0 DATE/TIME: 06/16/93 10:05
LAST UPDATED: 06/16/93 10:05

Job Title: 2E0C8 "D" NCP FLANGE BOLT BASELINE TORQUE DATA

STANDING REQUIREMENTS FOR USE OF THIS RWP
EACH RADIATION WORKER IS RESPONSIBLE FOR:

- KNOWING THEIR WORK AREA DOSE RATES.
- FOLLOWING REQUIREMENTS OF THIS RWP.
- BEING ALARA.
- HOUSEKEEPING.
- WEARING A POCKET OR ELECTRONIC DOSIMETER AND A TLD.
- FOLLOWING POSTED REQUIREMENTS.
- REVIEWING AREA RADIOLOGICAL PLAN VIEW WHEN AVAILABLE PRIOR TO ENTRY.
- NOTIFYING RADIATION PROTECTION PRIOR TO SWEEPING, BRUSHING, GRINDING, WELDING, OR USE OF COMPRESSED AIR IN CONTAMINATED AREAS.
- FOLLOWING POSTED DRESS CATEGORY REQUIREMENTS.
- WEARING MODESTY GARMENTS WHEN NOT WEARING PERSONAL OUTER CLOTHING.
- MONITORING PERSONNEL/TOOL/EQUIPMENT REQUIRED WHEN LEAVING RCA/RCZ.

DRESS CATEGORY AND TASK DESCRIPTION

A 1. PERSONNEL WORKING IN CLEAN AREAS.
E 2. PERSONNEL IN CLEAN AREAS HANDLING RADIOACTIVE MATERIALS WHENTHE POTENTIAL FOR CROSS CONTAMINATION EXISTS.
K 3. PERSONNEL WORKING IN DRY AREAS WHERE CONTAMINATION LEVELS DO NOT EXCEED 100,000 DPM. SEE NOTES 2,7,8
M 4. PERSONNEL WORKING IN DRY AREAS WHERE CONTAMINATION LEVELS DO NOT EXCEED 20 MRAD/HR. SEE NOTES 2,3,7,8
N 5. PERSONNEL WORKING IN WET AREAS OR DRY AREAS WHERE CONTAMINATION LEVELS EXCEED 20 MRAD/HR SEE NOTES 1,2,4,7,8
M 4. PERSONNEL WORKING IN DRY AREAS WHERE CONTAMINATION LEVELS ARE <50,000 DPM SEE NOTES 2,7,8

SPECIAL DOSIMETRY

RESPIRATORY
TASK DESCRIPTION
< 3,4,5,6 > FULL FACE PART (ADD HOOD)

SPECIAL INSTRUCTIONS/PRECAUTIONS

- NOTIFY RP PRIOR TO START OF WORK
- LOW EXPOSURE WAITING AREAS ARE IDENTIFIED
- NOTIFY RP PRIOR TO USING SOLVENTS ON CONTAMINATED MATERIALS
- NOTIFY RP PRIOR TO CHANGING WORK LOCATION
- UTILIZE TEMPORARY SHIELDING

COMMENTS

WHEN SAFETY GLASSES ARE WORN IN CONTAMINATED AREAS, ENSURE THAT THEY ARE SECURED TO PREVENT SLIPPING.
FACE SHIELDS MAY BE WORN TO PERVENT FACIAL CONTAMINATION WITH RP SUPERVISION APPROVAL.

DOSE ALARM: 50 MREM
DOSE RATE ALARM: 100 MREM/HR

APPROVED BY: JEM1822
DATE/TIME: 06/16/93 10:05

TERMINATED BY
DATE/TIME:

**Figure 4-1 Sample RWP**

RP Manual Section 16.1
Enclosure 5.1
Page 2 of 3

## RADIATION WORK PERMIT CONTINUATION SHEET

DATE: 6/16/93 TIME: 1005 (S)RWP#: 2009 REV: Ø PAGE 2 OF 3

| NOTES | |
|---|---|
| NOTE 1 : | A yellow hood may be substituted for a wetsuit hood when wet conditions do not cause a concern to the head area. |
| NOTE 2 : | When a respirator is used, an additional hood, yellow in color, shall be worn on the outside of the respirator. |
| NOTE 3 : | The outer set of coveralls should be yellow in color. |
| NOTE 4 : | Only the bottom half of the wetsuit is required when wet conditions do not cause a concern above the waist. |
| NOTE 5 : | Disposable and rubber shoe covers, cotton and rubber gloves may be worn without the sacksuit into contaminated areas with < 5000 dpm/100cm²βγ for short -duration into areas without obstructions with RP approval. |
| NOTE 7 : | Respiratory protection shall be used in areas where airborne radioactivity is > 10 DACs excluding noble gases. Respiratory protection should be considered when performing heavy work in areas with contamination levels of > 25,000 dpm/100cm²βγ or when performing light work in areas with contamination levels > 100,000 dpm/100cm²βγ |
| NOTE 8 : | Continuous coverage is required in extra high radiation areas or in areas where contamination levels are >100,000 dpm/100cm²βγ or where airborne radioactivity levels are >10 DAC's excluding noble gases. |
| NOTE 9 : | For workers who require multipack dosimetry, yellow PCs with multiple pockets shall be worn instead of the white PCs. |
| NOTE 10 : | A sacksuit is not required when the plant is in modes 1,2,3, or 4 |
| | |
| | |
| | |
| | |

Figure 4-2 Sample RWP.

RP Manual Section 16.1
Enclosure 5.1
Page 3 of 3

RADIATION WORK PERMIT CONTINUATION SHEET

DATE: 6/16/93 TIME: 1005 (S)RWP#: 2009 REV: Ø PAGE 3 OF 3

| WORKER CATEGORY | LIMITING CONDITIONS |
|---|---|
| THIS (S)RWP WILL BE REEVALUATED IF THE FOLLOWING CONDITIONS ARE EXCEEDED: | |
| A WORKER | HDPM – < 1000 dpm/100cm² βγ; HGA– 300 mrem/hr ; HDAC – 10 dacs excluding noble gases. |
| B WORKER | HDPM – < 1000 dpm/100cm² βγ; HGA– 300 mrem/hr ; HDAC – 10 dacs excluding noble gases. |
| C WORKER | HDPM – < 1000 dpm/100cm² βγ; HGA– 300 mrem/hr ; HDAC – 10 dacs excluding noble gases. |
| D WORKER | HDPM – < 5000 dpm/100cm² βγ; HGA – 300 mrem/hr ; HDAC – 10 dacs excluding noble gases. |
| E WORKER | HDPM – < 1000 dpm/100cm² βγ; HGA– 300 mrem/hr ; HDAC – 10 dacs excluding noble gases. |
| F WORKER | HDPM – < 5000 dpm/100cm² βγ; HGA – 300 mrem/hr ; HDAC – 10 dacs excluding noble gases. |
| G WORKER | HDPM – 10,000 dpm/100cm² βγ; HGA – 300 mrem/hr ; HDAC – 10 dacs excluding noble gases. |
| H WORKER | HDPM – 50,000 dpm/100cm² βγ; HGA – 300 mrem/hr ; HDAC – 40 dacs excluding noble gases. |
| I WORKER | HDPM – 50,000 dpm/100cm² βγ; HGA – 300 mrem/hr ; HDAC – 40 dacs excluding noble gases. |
| J WORKER | HDPM – 50,000 dpm/100cm² βγ; HGA – 300 mrem/hr ; HDAC – 40 dacs excluding noble gases. |
| K WORKER | HDPM – 100,000 dpm/100cm² βγ; HGA – 300 mrem/hr ; HDAC – 40 dacs excluding noble gases. |
| L WORKER | HDPM – 100,000 dpm/100cm² βγ; HGA – 300 mrem/hr ; HDAC – 40 dacs excluding noble gases. |
| M WORKER | HDPM – 20 mrad/hr/100cm² βγ; HGA – 300 mrem/hr ; HDAC – 40 dacs excluding noble gases. |
| N WORKER | Workers dose not to exceed 80% of their administrative limit ; HDAC – 40 DACS excluding noble gases. |
| O WORKER | Workers dose not to exceed 80% of their administrative limit ; HDAC – 40 DACS excluding noble gases. |
| P WORKER | HGA – 300 mrem/hr; HDAC – 40 DACS excluding noble gases. |
| Q WORKER | HGA – 300 mrem/hr; HDAC – 40 DACS excluding noble gases. |
| Z WORKER | Special dress as required by Radiation Protection. |

Figure 4-3 Sample RWP.

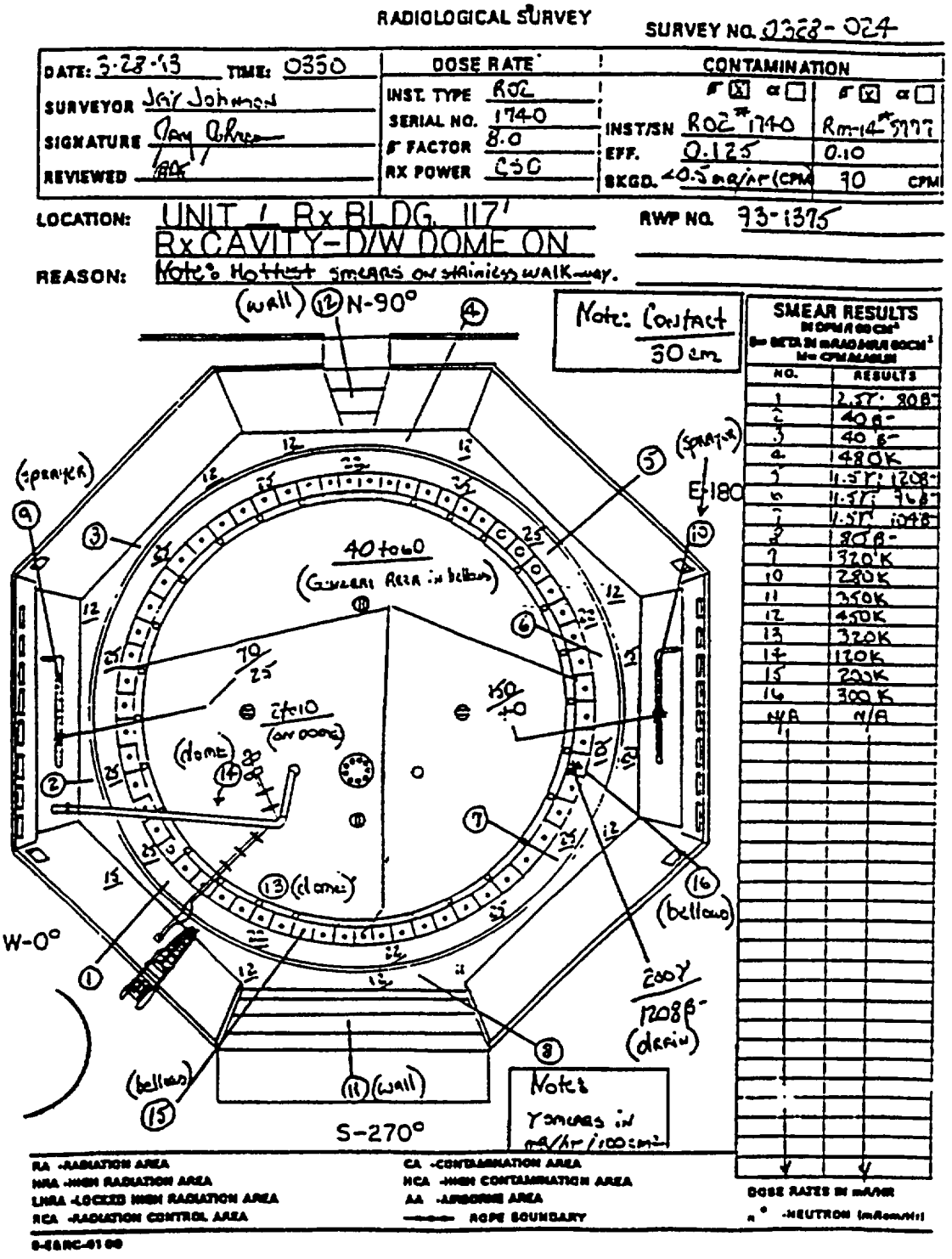



**Figure 4-5 Sample Survey.**

RADIOLOGICAL SURVEY

DATE 4/12/93 SURVEY # 0412 - 41

COUNTING INSTRUMENT USED BA-102 Sampler CFM x 28320 = cc/min x time x CF = volume (cc)

1) LOCATION UI 117' Refuel Bridge RWP # 93-1035

COMMENTS Test Refuel Bridge and man lights

SAMPLE ON 4/12/93 / 0950 (DATE / TIME)

SAMPLE OFF 4/12/93 / 1325 (DATE / TIME)

Resp. Type: [X] No. Resp. [ ] FFAP [ ] Airline [ ] SCBA [ ] Bubble Hood

Air Sample: [X] G/A [ ] B/Z [ ] Routine [ ] Boundary

Sampler Type: [X] LoVol [ ] Radeco [ ] Staplex [ ] CAM

Serial # PA-21 Sampler CFM 2.70 DAC P ____ I ____

TYPE: [X] β [ ] α [ ] γ

COUNTING ROOM # ____

| SAMPLE TIME (MIN) | CORR. FACTOR | VOLUME (CC) | COUNTED DATE | COUNTED TIME | COUNT TIME (MIN) | TOTAL COUNTS | BKG. (C/M) | NET (C/M) | EFF. | μCi/cc |
|---|---|---|---|---|---|---|---|---|---|---|
| 275 | 1.0 | 2.10E7 | 4/12 | 1343 | 1.0 | 593 | 28 | 565 | 0.228 | 5.31E-11 |

2) LOCATION UI 117' Refuel Floor (East) RWP # 93-1369

COMMENTS Routine

SAMPLE ON 4/12/93 / 0900 (DATE / TIME)

SAMPLE OFF 4/12/93 / 1310 (DATE / TIME)

Resp. Type: [X] No. Resp. [ ] FFAP [ ] Airline [ ] SCBA [ ] Bubble Hood

Air Sample: [ ] G/A [ ] B/Z [X] Routine [ ] Boundary

Sampler Type: [X] LoVol [ ] Radeco [ ] Staplex [ ] CAM

Serial # PA-126 Sampler CFM 2.75 DAC P ____ I ____

TYPE: [X] β [ ] α [ ] γ

COUNTING ROOM # ____

| SAMPLE TIME (MIN) | CORR. FACTOR | VOLUME (CC) | COUNTED DATE | COUNTED TIME | COUNT TIME (MIN) | TOTAL COUNTS | BKG. (C/M) | NET (C/M) | EFF. | μCi/cc |
|---|---|---|---|---|---|---|---|---|---|---|
| 310 | 1.0 | 2.41E7 | 4/12 | 1344 | 1.0 | 47 | 28 | 19 | 0.228 | 1.55E-12 |

3) LOCATION UI 117' Refuel Floor (West) RWP # 93-1369

COMMENTS Routine

SAMPLE ON 4/12/93 / 0910 (DATE / TIME)

SAMPLE OFF 4/12/93 / 1308 (DATE / TIME)

Resp. Type: [X] No. Resp. [ ] FFAP [ ] Airline [ ] SCBA [ ] Bubble Hood

Air Sample: [ ] G/A [ ] B/Z [X] Routine [ ] Boundary

Sampler Type: [X] LoVol [ ] Radeco [ ] Staplex [ ] CAM

Serial # PA-56 Sampler CFM 2.66 DAC P ____ I ____

TYPE: [X] β [ ] α [ ] γ

COUNTING ROOM # ____

| SAMPLE TIME (MIN) | CORR. FACTOR | VOLUME (CC) | COUNTED DATE | COUNTED TIME | COUNT TIME (MIN) | TOTAL COUNTS | BKG. (C/M) | NET (C/M) | EFF. | μCi/cc |
|---|---|---|---|---|---|---|---|---|---|---|
| 298 | 1.0 | 2.19E7 | 4/12 | 1345 | 1.0 | 454 | 28 | 426 | 0.228 | 3.84E-11 |

Surveyor David Reynolds Signature David Reynolds

Counted By S. Smith Reviewed By gjh

Figure 4-6 Sample Survey.

# Appendix 4-1

# Regulatory Guide 8.8

U.S. NUCLEAR REGULATORY COMMISSION

Revision 3
June 1978

# REGULATORY GUIDE

OFFICE OF STANDARDS DEVELOPMENT

## REGULATORY GUIDE 8.8

## INFORMATION RELEVANT TO ENSURING THAT OCCUPATIONAL RADIATION EXPOSURES AT NUCLEAR POWER STATIONS WILL BE AS LOW AS IS REASONABLY ACHIEVABLE

### A. INTRODUCTION

Paragraph 20.1(c) of 10 CFR Part 20, "Standards for Protection Against Radiation," states that licensees should make every reasonable effort to maintain exposures to radiation as far below the limits specified in Part 20 as is reasonably achievable. This guide provides information relevant to attaining goals and objectives for planning, designing, constructing, * | operating, and decommissioning a light-water reactor (LWR) nuclear power station to meet the criterion that exposures of station personnel[1] to radiation during routine operation of the station will be "as low as is reasonably achievable" (ALARA). This guide is also responsive to the admonition of the Federal Radiation Council (now EPA) that occupational radiation exposures be maintained ALARA. Major accident situations and emergency procedures are not within the scope of this guide.

Much of the information presented in this guide also is applicable to nuclear power stations other than those cooled with light water. The applicable goals and objectives should be used for all nuclear power stations until more specific goals and objectives are available for other types of power reactors.

### B. DISCUSSION

The relationship between radiation dose and biological effects is reasonably well known only for doses that are high compared with current annual dose limits and only when such doses are delivered at high dose rates.[2] An ad hoc committee of the National Council on Radiation Protection and Measurements (NCRP) (Ref. 1) chose in 1959 to make the cautious assumptions that a proportional relationship exists between dose and biological effects and that the effect is not dependent on dose rate. Essentially, this amounts to assumptions of a nonthreshold, "linear" (straight line) dose-effect relationship.

The International Commission on Radiological Protection ICRP), the Federal Radiation Council (FRC) whose functions now reside in the Environmental Protection Agency (EPA), and committees of the National Academy of Sciences/National Research Council (NAS/NRC) have used this hypothesis to estimate conservatively the number of possible biological effects that statistically may be associated with exposures to radiation.

The NAS/NRC Biological Effects of Ionizing Radiation (BEIR) Committee (Ref. 2) reiterated that the assumptions of a nonthreshold linear relationship between dose and biological effects independent of the dose rate should be applied for radiation protection purposes. This recommendation has been adopted by EPA (41 FR 28409) for the purpose of estimating the potential human health impact of low levels of ionizing radiation. The radiation protection goal is to reduce doses wherever and whenever reasonably achievable, thereby reducing the risk that is assumed (for radiation protection purposes) to be proportional to the dose.

In 1973, the ICRP (Ref. 3) stated:

"Whilst the values proposed for maximum permis-

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* Lines indicate substantive changes from previous issue.

[1] "Station personnel," as used in this guide, includes all persons working at the station, whether full-time or part-time and whether employed by the licensee or by a contractor for the licensee.

[2] Throughout this guide the word "dose" will allude to "dose equivalent," the term used for radiation protection purposes, with the unit expressed in "rems "

sible doses are such as to involve a risk which is small compared to the other hazards of life, nevertheless, in view of the incomplete evidence on which the values are based, coupled with the knowledge that certain radiation effects are irreversible and cumulative, it is strongly recommended that every effort be made to reduce exposure to all types of ionizing radiation to the lowest possible level."

Merely controlling the maximum dose to individuals is not sufficient; the collective dose to the group (measured in man-rems) also must be kept as low as is reasonably achievable. "Reasonably achievable" is judged by considering the state of technology and the economics of improvements in relation to all the benefits from these improvements. (However, a comprehensive consideration of risks and benefits will include risks from nonradiological hazards. An action taken to reduce radiation risks should not result in a significantly larger risk from other hazards.)

Under the linear nonthreshold concept, restricting the doses to individuals at a fraction of the applicable limit would be inappropriate if such action would result in the exposure of more persons to radiation and would increase the total man-rem dose. The radiation protection[3] community has recognized for many years that it is prudent to avoid unnecessary exposure to radiation and to maintain doses ALARA. In addition to reduced biological risks, the benefits of such practices may include avoidance of costs for extra personnel to perform maintenance activities and avoidance of nonproductive station shutdown time caused by restrictions on station personnel working in radiation areas.

Annual collective radiation dose equivalents received by personnel working at an LWR nuclear power station have ranged from less than 100 man-rems to over 5,000 man-rems (Refs. 4 and 5). Typically, annual collective dose equivalents range from 400 to 1,000 man-rems at LWR stations that have been in operation from 2 to 14 years and have generating capacities ranging from less than 100 MWe to 800 MWe. In view of the anticipated growth of nuclear power stations over the next few decades and the radiation exposure experience to date, additional efforts to reduce radiation doses to nuclear power station personnel are warranted.

The wide range in collective radiation doses to station personnel among the various stations appears to be primarily a function of doses received in maintenance operations in radiation areas. Some data are available to permit estimates of the distribution of doses among broad job categories and among the equipment systems or components that represent substantial sources of exposures. Doses to station personnel are influenced by many variables, including the ability of fuel elements to retain fission products, the extent of deposition of activated corrosion products throughout the primary and auxiliary coolant systems, the reliability of other specific equipment, the station layout, and radiation protection programs.

If design reviews or inspections had revealed that radiation exposures at nuclear power stations were unavoidable or that the cost of reducing the exposures would be unreasonable, the exposures might be considered ALARA by definition. However, this has not always been the case, and this guide is intended to assist in achieving a status wherein exposures are considered to be ALARA.

A major portion of the radiation exposure of station personnel is received during maintenance, radwaste handling, inservice inspection, refueling, and nonroutine operations (Ref. 6). The decommissioning process also has a potential for substantial exposures to personnel. Effective design of facilities and selection of equipment for systems that contain, collect, store, process, or transport radioactive material in any form will contribute to the effort to maintain radiation doses to station personnel ALARA.

Products of erosion or corrosion (i.e., "crud"[4]) that become mobile and are activated constitute an important (perhaps principal) source of radiation with respect to the exposure of station personnel. (Crud is accumulated in and transported by the coolant. Some components of the crud become radioactive when passing through the reactor core. Migration of crud to other systems occurs with coolant or steam. Specific radionuclides that have been identified in crud and that can contribute substantially to the radiation source are Co-58, Co-60, Mn-54, Zn-65, and Zr-95.)

Exposures of station personnel who service equipment contaminated by crud can generally be reduced substantially by minimizing the formation of crud and by designing or modifying equipment to minimize locations where crud can deposit and accumulate. Provisions for isolating components and flushing with crud-removing fluid such as demineralized water can often reduce accumulations prior to activities such as maintenance or equipment replacement.

Station and equipment layout also can affect the potential for radiation exposures. Exposures at sites where multiple radiation sources exist sometimes can be reduced by additional separation of individual sources. Adequate space for ease of maintenance and other operations can permit the tasks to be completed more quickly, thereby reducing the length of expo-

[3] The term "radiation protection," as used in this guide, is considered to be synonymous with the term "applied health physics"; i.e., the development and implementation of methods and procedures necessary to evaluate radiation hazards and to provide protection to man and his environment from unwarranted exposure.

[4] "Crud" is corrosion and erosion products and other solids that are formed by chemical and physical reaction between the reactor coolant and structural materials.

sures. Shielding by structural materials, equipment, and auxiliary or permanent shields can reduce exposures by isolating radiation sources. Where equipment components constitute a substantial radiation source that cannot be effectively reduced in place, features that permit the removal of such components for maintenance at remote locations often can be effective in reducing exposures. The use of remote-handling features also can reduce exposures of station personnel in certain instances.

Station technical and supervisory personnel, working closely with radiation protection personnel, can reduce exposures by planning activities of personnel who must enter radiation areas, by studying the actions and procedures of individuals working in such areas, and by conducting postoperation debriefings on projects resulting in substantial exposures to identify how procedures might be modified to reduce exposures on subsequent similar tasks. Training programs for all station personnel can establish and reinforce the principles of radiation protection as applied to specific job functions. By making personnel aware of the methods and the special equipment and protective equipment available to them, potential radiation doses can be reduced.

The concept of maintaining occupational radiation exposures ALARA does not embody a specific numerical guideline value at the present time. Rather, it is a philosophy that reflects specific objectives for radiation dose management in:

1. Establishing a program to maintain occupational radiation exposures ALARA;
2. Designing facilities and selecting equipment;
3. Establishing a radiation control program, plans, and procedures; and
4. Making supporting equipment, instrumentation, and facilities available.

When an adequate data base, including economic information, is available, the criteria for keeping annual collective doses to station personnel ALARA might be derived or selected in numerical terms. However, a data base of operating experience and cost information to provide quantitative guidance for establishing such criteria is not available at this time, and the criteria for meeting the provision of paragraph 20.1(c) of 10 CFR Part 20 must therefore take the form of qualitative guidance (e.g., goals, objectives, and statements of good practice).

The NRC staff has not performed a cost-benefit analysis for each of the considerations discussed or presented in Section C of this guide. This guide presents goals and objectives that were selected to satisfy the principles, philosophy, and criteria for maintaining occupational radiation exposures ALARA. Attaining these goals and objectives will require good engineering judgment on a case-by-case basis. A cost-benefit analysis may be helpful in arriving at the judgment, but it should not be the decisive factor in all cases.

The nuclear steam supply system (NSSS) vendor, the designer, the architect-engineer (A/E), the constructor, and the operator of the nuclear power facility each have responsibilities related to the effort of maintaining occupational radiation exposures ALARA. Thus, coordination and cooperation are essential to achieving these goals and objectives of maintaining occupational radiation exposures ALARA.

This guide is written primarily for the applicant or licensee. However, the designer, the A/E, and the constructor will find many of the guide's considerations helpful in the design and construction process to ensure that their efforts are consistent with the needs of the applicant or licensee to maintain radiation exposures ALARA.

Specific design or operational objectives for maintaining radiation exposures ALARA are suggested by the parameters that determine the magnitude of doses to station personnel, both as individuals and as a group. Doses to personnel in nuclear power stations are predominantly from external exposure, i.e., from radiation sources external to the body. However, there also exists a potential for doses from internal exposures, i.e., from radioactive materials taken into the body.

Important parameters in determining doses from external exposures are (1) the length of time that the receptor remains in the radiation field and (2) the intensity of the radiation field. Some degree of exposure of station personnel cannot be avoided during the operation and maintenance of nuclear power stations. However, there are many ways by which the exposures and resultant doses can be lowered by reducing the time interval of the exposure and the intensity of the radiation field. The intensity of the radiation field is determined by (1) the quantity of radioactive material, (2) the nature (i.e., characteristics) of the emitted radiation, (3) the nature of the shielding between the radiation source and the receptor, and (4) geometry (e.g., distances and dimensions).

Parameters important in determining doses from internal exposures are (1) the quantity of radioactive material taken into the body, (2) the nature (isotopical and body deposition characteristics) of the material, and (3) the time interval over which the material is retained by the body. The principal modes by which radioactive material can be taken into the body are (1) inhalation, (2) ingestion, (3) skin absorption, and (4) injection through wounds. At nuclear power stations, radioactive materials are generally confined, but some dispersion within the station is unavoidable and constitutes the source of (1) contaminated air and liquids that present the potential for intake by inhala-

tion and absorption and (2) contaminated surfaces that present the potential for intake by ingestion and through cuts or abrasions in the skin. Absorption generally is not an important intake mode at nuclear power stations except for tritium, which can be absorbed through the skin.

Consequently, the basic variables that can be controlled to limit doses from internal exposures are those that limit (1) the amount of contamination, (2) the dispersal of the contamination, and (3) the length of time that personnel must spend in contaminated areas. Protective equipment can keep the intake of the contaminant to a minimum. Physical and chemical methods can be used to hasten the elimination of radioactive material taken into the body; however, because of the risks associated with the use of these methods, they are reserved for very serious cases where the probability of experiencing biological effects is quite substantial, e.g., large intakes such as those that might occur in serious accident situations.

Objectives stated in this guide for maintaining occupational radiation exposures ALARA are derived by considering the parameters that affect dose, the variables that exist in the station design features, and the variables that can be provided by station administrative actions. Section C, Regulatory Position, states objectives in a manner that encourages innovation by permitting considerable flexibility on the part of the utility, the NSSS vendor, the designer, the constructor, and the A/E. However the regulatory position also describes a large number of specific concerns that should be addressed in meeting the goals and objectives.

## C. REGULATORY POSITION

The goals of the effort to maintain occupational radiation exposures ALARA are (1) to maintain the annual dose to individual station personnel as low as is reasonably achievable and (2) to keep the annual integrated (collective) dose to station personnel (i.e., the sum of annual doses (expressed in man-rems) to all station personnel) as low as is reasonably achievable.

The NRC staff believes that the stated objectives are attainable with current technology and with good operating practices. The costs for attaining these objectives have not been established and are expected to vary widely depending on the features of the specific power reactor facility and the method selected to accomplish the objectives. The favorable cost-benefit ratio for achieving some of these objectives may be obvious without a detailed study. For other objectives, however, a cost-benefit study might be required to determine whether the objectives are reasonably achievable. Doses to station personnel can affect station availability, and this factor should be considered in assessing the cost-benefit ratio.

Attaining the following objectives to the extent practicable throughout the planning, designing, constructing, operating, maintenance, and decommissioning of an LWR station will be considered to provide reasonable assurance that exposures of station personnel to radiation will be ALARA. The methods are deliberately stated such that considerable flexibility can be used in the manner by which the objectives can be achieved. Differences among stations might necessitate further innovation in methods used to achieve the objectives.

### 1. Program for Maintaining Station Personnel Radiation Doses ALARA

To attain the integrated effort needed to keep exposures of station personnel ALARA, each applicant and licensee should develop an ALARA program that reflects the efforts to be taken by the utility, nuclear steam supply system vendor, and architect-engineer to maintain radiation exposure ALARA in all phases of a station's life. This program should be in written form and should contain sections that cover the generally applicable guidance presented in this guide, as a minimum, and more specific guidance as required to address the particular LWR that is the subject of the licensing action. This program may be combined with the station's radiation protection manual, safety analysis report, or other documents or submittals. It need not be an independent document.

#### a. Establishment of a Program To Maintain Occupational Radiation Doses ALARA

(1) A management policy for, and commitment to, ensuring that the exposure of station personnel to radiation will be ALARA should be established.

(2) The policy and commitment should be reflected in written administrative procedures and instructions for operations involving potential exposures of personnel to radiation and should be reflected in station design features. Instructions to designers, constructors, vendors, and station personnel specifying or reviewing station features, systems, or equipment should reflect the goals and objectives to maintain occupational radiation exposures ALARA. (Few utilities design or build their nuclear power stations; but as *customers* of designers and builders, utilities should expect the designers and builders to be responsive to their needs and instructions.)

#### b. Organization, Personnel, and Responsibilities

(1) In view of the need for upper-level management support, responsibility and authority for implementing the program to maintain occupational radiation exposures ALARA should be assigned to an individual (or committee) with organizational freedom to ensure development and implementation. Responsibilities and authorities should include:

(a) Ensuring that a corporate program that integrates management philosophy and regulatory re-

quirements is established, with specific goals and objectives for implementation included;

(b) Ensuring that an effective measurement system is established and used to determine the degree of success achieved by station operations with regard to the program goals and specific objectives;

(c) Ensuring that the measurement system results are reviewed on a periodic basis and that corrective actions are taken when attainment of the specific objectives appears to be jeopardized;

(d) Ensuring that the authority for providing procedures and practices by which the specific goals and objectives will be achieved is delegated; and

(e) Ensuring that the resources needed to achieve goals and objectives to maintain occupational radiation exposures ALARA are made available.

In view of the responsibilities required to implement a program to maintain occupational radiation exposures ALARA, the individual (or committee) selected for this function might also be chosen to coordinate the effort among the several corporate functional groups (such as the operations, maintenance, technical support, engineering, safety, and radiation protection groups) and to represent the corporate interests in dealing with the NSSS designer, vendor, A/E, and builder during the design and construction phases. If the expertise for performing this function is not within the corporation when the station is in the design stage, consultants who possess the required expertise should be used. The utility should obtain assurance that available data and experience obtained from similar nuclear power stations are considered and reflected in the work of the NSSS designer, vendor, A/E, and builder so as to provide features in the new station that permit an effective ALARA program.

(2) The Plant Manager (Superintendent or equivalent) is responsible for all aspects of station operation, including the onsite radiation protection program.

Responsibilities of the Plant Manager with respect to a program to maintain occupational radiation exposures ALARA should include:

(a) Ensuring support from all station personnel;

(b) Participating in the selection of specific goals and objectives for the station;

(c) Supporting the onsite Radiation Protection Manager (RPM) in formulating and implementing a station program in maintaining occupational radiation exposures ALARA; and

(d) Expediting the collection and dissemination of data and information concerning the program to the corporate management.

(3) The Radiation Protection Manager (RPM) (onsite) has a safety function and responsibility to both employees and management that can be best fulfilled if the individual is independent of station divisions, such as operations, maintenance, or technical support, whose prime responsibility is continuity or improvement of station operability. The RPM should have direct recourse to responsible management personnel in order to resolve questions related to the conduct of the radiation protection program.

(The specific responsibilities given here for the RPM are illustrative and not intended to be all-inclusive with respect to the ALARA program or effort. They do not include any of the responsibilities in areas other than ALARA efforts.)

Responsibilities of the RPM with respect to a program to maintain occupational radiation exposures ALARA should include:

(a) Participating in design reviews for facilities and equipment that can affect potential radiation exposures;

(b) Identifying locations, operations, and conditions that have the potential for causing significant exposures to radiation;

(c) Initiating and implementing an exposure control program;

(d) Developing plans, procedures, and methods for keeping radiation exposures of station personnel ALARA;

(e) Reviewing, commenting on, and recommending changes in job procedures to maintain exposures ALARA;

(f) Participating in the development and approval of training programs related to work in radiation areas or involving radioactive materials;

(g) Supervising the radiation surveillance program to maintain data on exposures of and doses to station personnel, by specific job functions and type of work;

(h) Supervising the collection, analysis, and evaluation of data and information attained from radiological surveys and monitoring activities;[5]

(i) Supervising, training, and qualifying the radiation protection staff of the station; and

(j) Ensuring that adequate radiation protection coverage is provided for station personnel during all working hours.

[5] Data collected during outages can indicate trends of radiation buildup in equipment that can permit estimates of probable radiation levels to be encountered during subsequent outages.

Qualifications[6] needed for the RPM job, as well as those needed for other positions in organizations operating nuclear power stations, are presented in Regulatory Guide 1.8, "Personnel Selection and Training."

### c. Training and Instruction

A training program in the fundamentals of radiation protection and in station exposure control procedures should be established. It should include instructing all personnel whose duties require (1) working with radioactive materials, (2) entering radiation areas, or (3) directing the activities of others who work with radioactive materials or enter radiation areas. The training program also should include sufficient instruction in the biological effects of exposures to radiation to permit the individuals receiving the instruction to understand and evaluate the significance of radiation doses in terms of the potential risks.

The training should be commensurate with the duties and responsibilities of those receiving the instructions, as well as with the magnitude of the potential doses and dose rates that can be anticipated. Personnel (including contractor personnel) who direct the activities of others should be familiar with the licensee's radiation control program and should have the authority to implement the licensee's commitment to ensure the radiation exposures of station personnel will be ALARA.

The training program should include instruction on (1) radiation protection rules for the station and (2) the applicable Federal regulations. Copies of these rules and regulations should be made available to those receiving the instructions. The training program should be approved by the RPM and presented by competent instructors. The information presented in the training program should be reviewed periodically and modified, where necessary, to reflect contemporary techniques and adjustments based on experience in station operations. Instruction of station personnel should stress the importance of exposure-reduction efforts by every individual and should emphasize the need for feedback of information obtained when similar tasks were performed previously.

Station personnel should receive instruction at periodic intervals to reinforce their knowledge and keep it current. Station personnel whose duties do not require entering radiation areas or working with radioactive materials should receive sufficient instruction in radiation protection and station rules and regulations to understand why they should not enter such areas.

Training programs that have as their goal an increase in craft skills provide a broader base of knowledgeable station personnel available to service equipment in radiation areas and permit the services to be performed more reliably and more efficiently. This can promote lower individual and collective dose levels.

### d. Review of New or Modified Designs and Equipment Selection

(1) Since several groups within a utility (e.g., maintenance, operations, radiation protection, technical support, engineering, and safety groups) are interested in station design and equipment selection, the utility should ensure that these groups are adequately represented in the review of the design of the facility and the selection of equipment. A coordinated effort by the several functional groups within the utility is required to ensure that station features will permit the goals and objectives of the ALARA program to be achieved. Although the A/E and designers greatly influence station design features, utilities should not delegate all responsibilities for station design review and equipment selection to the NSSS designer, vendor, or A/E.

(2) Design concepts and station features should reflect consideration of the activities of station personnel (such as maintenance, refueling, inservice inspections, processing of radioactive wastes, decontamination, and decommissioning) that might be anticipated and that might lead to personnel exposure to substantial sources of radiation. Radiation protection aspects of decommissioning should be factored into planning, designing, construction, and modification activities. Station design features should be provided to reduce the anticipated exposures of station personnel to these sources of radiation to the extent practicable.

(3) Specifications for equipment should reflect the objectives of the ALARA program, including considerations of reliability, serviceability, limitations of internal accumulations of radioactive material, and other features addressed in this guide. Specifications for replacement equipment also should reflect modifications based on experience gained from using the original equipment.

## 2. Facility and Equipment Design Features

Radiation sources within a nuclear power station differ appreciably with respect to location, intensity, and characteristics. The magnitude of the dose rates that results from these sources is dependent on many

[6] Consideration has been given to peer group certification, i.e., certification of health physicists by the American Board of Health Physics (ABHP), as representing evidence of adequate qualifications for RPM candidates. While the staff believes that peer group certification is desirable, the present ABHP certification is not necessarily specifically applicable to applied health physics or radiation protection needs in nuclear power stations. However, the staff is discussing with the ABHP the prospects for a special certification program specifically directed toward the needs of radiation protection personnel at nuclear power stations.

factors, including the facility and equipment design, layout, mode and length of operation, and radiation source strength and characteristics.

To provide a basis for design, the quantity and isotopic composition of the radioactive material that can be anticipated to be contained, deposited, or accumulated in the station equipment should be estimated. Fission product source terms should be estimated using these bases: (1) an offgas rate of 100,000 $\mu$Ci/sec after 30 minutes delay for BWRs and (2) 0.25% fuel cladding defects for PWRs. Activation source terms, including activated corrosion products, should be based on measurements and experience gained from operating stations of similar design. ANSI N237-1976 (Ref. 7) is based on such experience and provides information that can be used as a basis for estimating activation source terms. When operating measurements are used, extrapolation of data to equilibrium conditions may be needed to estimate ultimate activation source terms. Neutron and prompt gamma source terms should be based on applicable operating experience and reactor core physics calculations.

ALARA program objectives are presented below for each of several station features or functions. Each statement of objective is followed by a number of specific concerns or suggestions that should be addressed.

**a. Access Control of Radiation Areas**

To avoid unnecessary and inadvertent exposures of personnel to radiation, the magnitude of the potential dose rates at all locations within the station should be estimated during station design. Actual dose rates should be measured periodically during operation to determine current exposure potentials. Zones associated with the higher dose rates should be kept as small as reasonably achievable consistent with accessibility for accomplishing the services that must be performed in those zones, including equipment laydown requirements. Radiation zones where station personnel spend substantial time should be designed to the lowest practical dose rates.

(It is common practice to identify "radiation zones" within a nuclear power station. The zone designations are established to reflect the design maximum dose rates that may exist in areas within the station where station personnel must have access to perform required services. Several systems for designating "radiation zones" currently exist among the utilities, and ANSI Committee 6.7 is developing a standard that should prove useful in attaining common designations and terminology in this matter. To avoid ambiguity, no reference to radiation zone numbers is made in this guide at this time.)

A system should be established to permit effective control over personnel access to the radiation areas and control over the movement of sources of radiation within the station. Where high radiation areas (>100 mrem/h) exist, § 20.203 of 10 CFR Part 20 requires that station design features and administrative controls provide effective ingress control, ease of egress, and appropriate warning devices and notices. Access control of radiation areas also should reflect the following considerations:

(1) Extraordinary design features are warranted to avoid any potential dose to personnel that is large enough to cause acute biological effects and that could be received in a short period of time. Positive control of ingress to such areas, permanent shielding, source removal, or combinations of these alternatives can reduce the dose potential.

(2) Administrative controls such as standard operating procedures can be effective in preventing inadvertent exposures of personnel and the spread of contamination when radioactive material or contaminated equipment must be transported from one station location to another and when the route of transport through lower radiation zones or "clean" areas cannot be avoided.

(3) Station features such as platforms or walkways, stairs, or ladders that permit prompt accessibility for servicing or inspection of components located in higher radiation zones can reduce exposure of personnel who must perform these services.

**b. Radiation Shields and Geometry**

Radiation shields should be designed using the design basis assumptions explained in regulatory position 2 and conservative assumptions for geometries. Calculational methods known to provide reliable and accurate results (i.e., methods and modeling techniques that have been demonstrated to give acceptable accuracy in analyses similar to the problem of concern) should be used to determine appropriate shield thicknesses. Shield design features should reflect the following considerations to maintain occupational radiation exposures ALARA:

(1) Exposure of personnel servicing a specific component (such as a pump, filter, or valve) to radiation from other components containing radioactive material can be reduced by providing shielding between the individual components that constitute substantial radiation sources and the receptor.

(2) Where it is impracticable to provide permanent shielding for individual components that constitute substantial radiation sources, the exposure of personnel maintaining such components can be reduced (a) by providing as much distance as practicable between the serviceable components and the substantial radiation sources in the area and (b) by providing temporary shields around components that contribute substantially to the dose rate.

(3) Potential exposure of station personnel to radiation from certain systems containing radiation sources can be reduced by means of a station layout that permits the use of distance and shielding between the sources and work locations. These systems include (but are not limited to) the NSSS and the reactor water cleanup, offgas treatment, solid waste treatment, and storage systems, as well as systems infrequently containing radiation sources such as the standby gas treatment and residual heat removal systems.

Radiation from an operating BWR turbine can constitute a substantial source of exposure for construction personnel or others who have access to the site for extended periods of time if insufficient shielding is provided.

(4) Streaming or scattering of radiation from locally shielded components (such as cubicles) can be reduced by providing labyrinths for access. However, such labyrinths or other design features of the cubicle should permit the components to be removed readily from the cubicle for repair or replacement where such work is expected or anticipated. Single-scatter labyrinths may be inadequate if the cubicle contains a substantial radiation source.

(5) Streaming of radiation into accessible areas through penetrations for pipes, ducts, and other shield discontinuities can be reduced (a) by means of layouts that prevent substantial radiation sources within the shield from being aligned with the penetrations or (b) by using "shadow" shields such as shields of limited size that attenuate the direct radiation component. Streaming also can occur through roofs or floors unless adequate shielding encloses the source from all directions.

(6) The exposure of station personnel to radiation from pipes carrying radioactive material can be reduced by means of shielded chases.

(7) Design features that permit the rapid removal and reassembly of shielding, insulation, and other material from equipment that must be inspected or serviced periodically can reduce the exposure of station personnel performing these activities.

(8) Space within cubicles and other shielding to provide laydown space for special tools and ease of servicing activities can reduce potential doses by permitting the services to be accomplished expeditiously, thus reducing exposure time.

(9) The exposure of personnel who service components that constitute substantial radiation sources or are located in high radiation fields can be minimized by removing the components and transporting them to low radiation zones where shielding and special tools are available. Design features that permit the prompt removal and installation of these components can reduce the exposure time.

(10) Floor and equipment drains, piping, and sumps that are provided to collect and route any contaminated liquids that might leak or be spilled from process equipment or sampling stations can become substantial radiation sources. The drain lines can be located in concrete floors, concrete ducts, columns, or radwaste pipe chases to provide shielding. These systems can also become a source of airborne contamination because of the potential for gases to form in, and be released by, such systems (see regulatory position 2.d(6)).

**c. Process Instrumentation and Controls**

Appropriate station layout and design features should be provided to reduce the potential doses to personnel who must operate, service, or inspect station instrumentation and controls. The following considerations should be reflected in selecting the station features:

(1) The exposure of personnel who must manually operate valves or controls can be reduced through the use of "reach rods" or remotely operated valves or controls. However, these devices can require lubrication and maintenance that can be the source of additional exposures, and these factors should be taken into consideration.

(2) The exposure of personnel who must view or operate instrumentation, monitors, and controls can be reduced by locating the readouts or control points in low radiation zones.

(3) Instrumentation must satisfy functional requirements, but the exposure of personnel can be reduced if the instruments are designed, selected, specified, and located with consideration for long service life, ease and low frequency of maintenance and calibration, and low crud accumulation. Operating experience should be recorded, evaluated, and reflected in the selection of replacement instrumentation.

(4) The use of instrumentation that contains minimal quantities of contaminated working fluid (e.g., pressure transducers rather than bellows-type pressure gauges) can reduce the potential for exposure at the readout locations.

**d. Control of Airborne Contaminants and Gaseous Radiation Sources**

Station design features should be provided in all station work areas to limit the average concentrations of radioactive material in air to levels well below the values listed in Appendix B, Table 1, Column 1 of 10 CFR Part 20. Effective design features can minimize the occurrence of occasional increases in air contamination and the concentrations and amounts of contaminants associated with any such occasional increases. Designs that permit repeated, identified releases of large amounts of radioactive materials into the air

spaces occupied by personnel are contrary to a program to maintain occupational radiation exposures ALARA.

Station design features should provide for protection against airborne radioactive material by means of engineering controls such as process, containment, and ventilation equipment. The routine provision of respiratory protection by use of individually worn respirators rather than engineered design features is generally unacceptable. The use of respirators, however, might be appropriate in certain nonroutine or emergency operations when the application of engineering controls is not feasible or while such controls are being installed.

The approved use of respirators is subject to the requirements of § 20.103, "Exposure of Individuals to Concentrations of Radioactive Materials in Air in Restricted Areas," of 10 CFR Part 20 and to regulatory guidance on acceptable use. (See Regulatory Guide 8.15, "Acceptable Programs for Respiratory Protection," and NUREG-0041, "Manual of Respiratory Protection Against Airborne Radioactive Materials" (Ref. 8).) Design features of the station ventilation system and gaseous radwaste processing systems should reflect the following considerations:

(1) The spread of airborne contamination within the station can be limited by maintaining air pressure gradients and airflows from areas of low potential airborne contamination to areas of higher potential contamination. Periodic checks would ensure that the design pressure differentials are being maintained.

(2) Effectively designed ventilation systems and gaseous radwaste treatment systems will contain radioactive material that has been deposited, collected, stored, or transported within or by the systems. Exposures of station personnel to radiation and to contamination from ventilation or gaseous radwaste treatment components occur as a result of the need to service, test, inspect, decontaminate, and replace components of the systems or perform other duties near these systems. Potential doses from these systems can be minimized by providing ready access to the systems, by providing space to permit the activities to be accomplished expeditiously, by separating filter banks and components to reduce exposures to radiation from adjacent banks and components, and by providing sufficient space to accomodate auxiliary ventilation or shielding of components.

(3) Auxiliary ventilation systems that augment the permanent system can provide local control of airborne contaminants when equipment containing potential airborne sources is opened to the atmosphere. Two types of auxiliary ventilation systems have proved to be effective. In areas where contaminated equipment must be opened frequently, dampers and fittings can be provided in ventilation ducts to permit the attachment of flexible tubing or "elephant trunks" without imbalancing the ventilation system. In areas where contaminated equipment must be opened infrequently, portable auxiliary ventilation systems featuring blowers, HEPA filters, and activated charcoal filters (where radioiodine might be anticipated) on carts can be used effectively. Portable auxiliary ventilation systems should be tested frequently to verify the efficiency of the filter elements in their mountings. When the efficiency has been verified, the system may be exhausted to the room or the ventilation exhaust duct without further treatment and thus imbalance of the permanent ventilation system can be avoided.

(4) Machining of contaminated surfaces (e.g., welding, grinding, sanding, or scaling) or "plugging" of leaking steam generator or condenser tubes can be substantial sources of airborne contamination. These sources can be controlled by using auxiliary ventilation systems.

(5) Sampling stations for primary coolant or other fluids containing high levels of radioactive material can constitute substantial sources of airborne contamination. Such sources can be controlled by using auxiliary ventilation systems.

(6) Wet transfer or storage of potentially contaminated components will minimize air contamination. This can be accomplished by keeping contaminated surfaces wet, by spraying, or, preferably, by keeping such surfaces under water.

**e. Crud Control**

Design features of the primary coolant system, the selection of construction materials that will be in contact with the primary coolant, and features of equipment that treat primary coolant should reflect considerations that will reduce the production and accumulation of crud in stations where it can cause high exposure levels. The following items should be considered in the crud control effort:

(1) Production of Co-58 and Co-60, which constitute substantial radiation sources in crud, can be reduced by specifying, to the extent practicable, low-nickel and low-cobalt bearing materials for primary coolant pipe, tubing, vessel internal surfaces, heat exchangers, wear materials, and other components that are in contact with primary coolant. Alternative materials for hard facings of wear materials of high-cobalt content should be considered where it is shown that these high-cobalt materials contribute to the overall exposure levels. Such consideration should also take into account potential increased service/repair requirements and overall reliability of the new material in relation to the old. Alternative materials for high-nickel alloy materials (e.g., Inconel 600) should be considered where it is shown that these materials contribute to overall exposure levels. Such consideration should also take into account potential increased

service/repair requirements and overall reliability of the new materials in relation to the old.

(2) Loss of material by erosion of load-bearing hard facings can be reduced by using favorable geometrics and lubricants, where practicable, and by using controlled leakage purge across journal sleeves to avoid entry of particles into the primary coolant.

(3) Loss of material by corrosion can be reduced by continuously monitoring and adjusting oxygen concentration and pH in primary coolant above 250°F and by using bright hydrogen-annealed tubing and piping in the primary coolant and feedwater systems.

(4) Consideration should be given to cleanup systems (e.g., using graphite or magnetic filters) for removal of crud from the primary coolant during operation.

(5) Deposition of crud within the primary coolant system can be reduced by providing laminar flow and smooth surfaces for coolant and by minimizing crud traps in the system to the extent practicable.

**f. Isolation and Decontamination**

Potential doses to station personnel who must service equipment containing radioactive sources can be reduced by removing such sources from the equipment (decontamination), to the extent practicable, prior to servicing. Serviceable systems and components that constitute a substantial radiation source should be designed, to the extent practicable, with features that permit isolation and decontamination. Station design features should consider, to the extent practicable, the ultimate decommissioning of the facility and the following concerns:

(1) The necessity for decontamination can be reduced by limiting, to the extent practicable, the deposition of radioactive material within the processing equipment—particularly in the "dead spaces" or "traps" in components where substantial accumulations can occur. The deposition of radioactive material in piping can be reduced and decontamination efforts enhanced by avoiding stagnant legs, by locating connections above the pipe centerline, by using sloping rather than horizontal runs, and by providing drains at low points in the system.

(2) The need to decontaminate equipment and station areas can be reduced by taking measures that will reduce the probability of release, reduce the amount released, and reduce the spread of the contaminant from the source (e.g., from systems or components that must be opened for service or replacement). Such measures can include auxiliary ventilation systems (see regulatory position 4.b), treatment of the exhaust from vents and overflows (see regulatory position 2.h(8)), drainage control such as curbing and floors sloping to local drains, or sumps to limit the spread of contamination from leakage of liquid systems.

(3) Accumulations of crud or other radioactive material that cannot be avoided within components or systems can be reduced by providing features that will permit the recirculation or flushing of fluids with the capacity to remove the radioactive material through chemical or physical action. The fluids containing the contaminants will require treatment, and this source should be considered in sizing station radwaste treatment systems.

(4) Continuity in the functioning of processing or ventilation systems that are important for controlling potential doses to station personnel can be provided during servicing of the systems if redundant components or systems are available so that the component (with associated piping) being serviced can be isolated.

(5) The potential for contamination of "clean services" (such as station service air, nitrogen, or water supply) from leakage from adjacent systems containing contaminants can be reduced by separating piping for these services from piping that contains radioactive sources. Piping that carries radioactive sources can be designed for the lifetime of the station, thus avoiding the necessity for replacement (and attendant exposures) and lessening the potential for contamination of clean services if it is impracticable to provide isolation through separate chases.

(6) Surfaces can be decontaminated more expeditiously if they are smooth, nonporous, and free of cracks, crevices, and sharp corners. These desirable features can be realized by specifying appropriate design instructions, by giving attention to finishing work during construction or manufacture, and by using sealers (such as special paints) on surfaces where contamination can be anticipated. (ANSI N101.2 provides helpful guidance on this matter (Ref. 9).)

(7) Where successful decontamination of important systems could be prevented by an anticipated failure of a critical component or feature, additional features that permit alternative decontamination actions can be provided.

(8) Contaminated water and deposited residues in spent fuel storage pools contribute to the exposure at accessible locations in the area. Treatment systems that remove contaminants from the water can perform more efficiently (a) if intake and discharge points for the treatment systems are located to provide enhanced mixing and to avoid stagnation areas in the pool and (b) if pool water overflows and skimmer tanks are provided. Fluid jet or vacuum-cleaner-type agitators can help reduce the settling of crud on surfaces of the pool system.

### g. Radiation Monitoring Systems

Central or "built-in" monitoring systems that give information on the dose rate and concentration of airborne radioactive material in selected station areas can reduce the exposure of station personnel who would be required to enter the areas to obtain the data if such systems were not provided. These systems also can provide timely information regarding changes in the dose rate or concentrations of airborne radioactive material in the areas. (The installation of a central monitoring system is easier and less expensive if it is a part of the original station design.) The selection or design and installation of a central monitoring system should include consideration of the following desirable features:

(1) Readout capability at the main radiation protection access control point;

(2) Placement of detectors for optimum coverage of areas (Ref. 10);

(3) Circuitry that indicates component failure;

(4) Local alarm and readout;

(5) Clear and unambiguous readout;

(6) Ranges adequate to ensure readout of the highest anticipated radiation levels and to ensure positive readout at the lowest anticipated levels; and

(7) Capability to record the readout of all systems.

### h. Resin and Sludge Treatment Systems

Systems used to transport, store, or process resins or slurries of filter sludge present a special hazard because of the concentrated nature of the radioactive material. Design features for resin- and sludge-handling systems should reflect this concern and the following specific considerations:

(1) The accumulation of radioactive material in components of systems used to process resin and sludges can be reduced by:

(a) Reducing the length of piping runs;

(b) Using larger diameter piping (to minimize plugging);

(c) Reducing the number of pipe fittings;

(d) Avoiding low points and dead legs in piping;

(e) Using gravitational flow to the extent practicable; and

(f) Minimizing flow restrictions of processed material.

(2) The need for maintenance and the presence of intense local radiation sources can be reduced by:

(a) Using full-ported valves constructed such that the slurry will not interfere with the opening or closing of the valve and

(b) Avoiding cavities in valves.

(3) The deposition of resin and sludge that would occur if elbow fittings were used can be reduced by using pipe bends of at least five pipe diameters in radius. Where pipe bends cannot be used, long radius elbows are preferred.

(4) Smoother interior pipe surfaces at connections (with attendant reductions in friction losses, deposition of material, and tendencies to "plug") can be achieved by using butt welds rather than socket welds and by using consumable inserts rather than backing rings.

(5) Where the use of tees cannot be avoided, line losses can be reduced if the flow is through the run (straight section) of the tee, and accumulations of material in the branch of the tee can be reduced by orienting the branch horizontally or (preferably) above the run.

(6) Slurry piping is subject to plugging that may require backflushing from the tank and equipment isolation valves and pressurizing with water, nitrogen, or air to "blow out" plugged lines. However, the use of pressurized gas for blowing out lines can present a potential contamination source and may not be effective in relieving plugged lines.

(7) Water, air, or nitrogen for sparging can be used to fluidize resins or sludges in storage tanks, The use of gases, however, presents a potential source of airborne contamination and tank rupture from overpressures.

(8) The spread of contamination by the loss of resin or sludge through overflows and vents can be reduced by using screens, filters, or other features that will collect and retain solids. However, such features generally require cleaning by remote flushing, by rapid replacement, or by other means to reduce exposures during servicing.

Consideration should be given to ANS N197, "Design and Performance of BWR Liquid Radioactive Waste Processing Systems (N18)" (Ref. 11); ANS 55.1, "Design Criteria for the Solid Radwaste Processing System of BWR, PWR, and HTGR" (Ref. 12); and ANS N199, "PWR Liquid Waste System Design (N18)" (Ref. 13). These standards cover some aspects of slurry systems.

### i. Other Features

Station layout and station tasks should be reviewed to identify and provide special features that complement the ALARA program. Station design should reflect consideration of the following concerns:

(1) The selection of radiation-damage-resistant materials for use in high radiation areas can reduce the need for frequent replacement and can reduce the probability of contamination from leakage.

(2) The use of stainless steel for constructing or lining components, where it is compatible with the process, can reduce corrosion and can provide options for decontamination methods.

(3) Field-run piping that carries radioactive material can cause unnecessary exposures unless due consideration is given to the routing. Such unnecessary exposures can be avoided if the routing is accomplished under the cognizance of an individual familiar with the principles of radiation protection or if a detailed piping layout is provided, i.e., if the piping is not field-run.

(4) Where filters or other serviceable components can constitute substantial radiation sources, exposures can be reduced by providing features that permit operators to avoid the direct radiation beam and that provide remote removal, installation, or servicing. Standardization of filters should be considered.

(5) The servicing of valves can be a substantial source of doses to station personnel. These doses can be reduced by providing adequate working space for easy accessibility and by locating the valves in areas that are not in high radiation fields.

(6) Leakage of contaminated coolant from the primary system can be reduced by using live-loaded valve packings and bellow seals.

(7) Potential doses from servicing valves and from leakage can be reduced by specifying and installing reliable valves for the required service, by using radiation-damage-resistant seals and gaskets, and by using valve back seats. The use of straight-through valve configurations can avoid the buildup of accumulations in internal crevices and the discontinuities that exist in valves of other configurations. In most cases, valves can be installed in the "stem-up" orientation to facilitate maintenance and to minimize crud traps. The desired features are reliability, good performance, and the ability to be maintained infrequently and rapidly.

(8) Leaks from pumps can be reduced by using canned pumps where they are compatible with the service needs, provided that lower personnel exposures can be achieved thereby. If mechanical seals are used on a pump in a slurry service, features that permit the use of flush water to clean pump seals can reduce the accumulation of radioactive material in the seals. Drains on pump housings can reduce the radiation field from this source during servicing. Provision for the collection of such leakage or disposal to a drain sump is appropriate.

(9) The sources of radiation such as sedimentation that occurs in tanks used to process liquids containing radioactive material and residual liquids can be reduced when servicing by draining the tanks. The design can include sloping the tank bottoms toward outlets leading to other reprocessing equipment and, where practicable, providing built-in spray or surge features.

(10) Spare connections on tanks or other components located in higher radiation zones may be desirable to provide flexibility in operations. Exposures of personnel can be avoided if these connections are provided as a part of the original equipment rather than by subsequent modification of the equipment in the presence of radiation.

(11) Inspections to satisfy the ASME Code (Ref. 14) and regulatory requirements can result in exposures of station personnel to radiation. Many of the objectives presented above will aid in reducing potential exposures to personnel who perform the required inspections. Station features and design should, to the extent practicable, permit inspections to be accomplished expeditiously and with minimal exposure of personnel. The effort to maintain occupational radiation exposures ALARA can also be aided by prompt accessibility, shielding and insulation that can be quickly removed and reinstalled, and special tools and instruments that reduce exposure time or permit remote inspection of components or equipment containing potential radiation sources.

(12) Components can be removed from processing systems more expeditiously if adequate space is provided in the layout of the system and if the interconnections permit prompt disconnects.

(13) Station features that provide a favorable working environment such as adequate lighting, ventilation, working space, and accessibility (via such means as working platforms, cat walks, and fixed ladders) can promote work efficiency.

(14) The exposure of station personnel who must replace lamps in high radiation areas can be reduced by using extended service lamps and by providing design features that permit the servicing of the lamps from lower radiation areas.

(15) An adequate emergency lighting system can reduce potential exposures of station personnel by permitting prompt egress from high radiation areas if the station lighting system fails.

### 3. Radiation Protection Program

A substantial portion of the radiation dose to station personnel is received while they are performing services such as maintenance, refueling, and inspection in high radiation areas. The objectives that were presented in regulatory position 2 can provide station design features conducive to an effective program to

maintain occupational radiation exposures ALARA. However, an effective program also requires station operational considerations in terms of procedures, job planning, recordkeeping, special equipment, operating philosophy, and other support. This section deals with the manner in which the station administrative efforts can influence the variables of (1) the number of persons who must enter high radiation areas or contaminated areas, (2) the period of time the persons must remain in these areas, and (3) the magnitude of the potential dose.

**a. Preparation and Planning**

Before entering radiation areas where significant doses could be received, station personnel should have the benefit of preparations and plans that can ensure the exposures are ALARA while the personnel are performing the services. Preparations and plans should reflect the following considerations:

(1) A staff member who is a specialist in radiation protection can be assigned the responsibility for contributing to and coordinating ALARA efforts in support of operations that could result in substantial individual and collective dose levels.

(2) To provide the bases for planning the activity, surveys can be performed to ascertain information with respect to radiation, contamination, airborne radioactive material, and mechanical difficulties that might be encountered while performing services.

(3) Radiation surveys provided in conjunction with inspections or other activities can define the nature of the radiation fields and identify favorable locations where personnel may take advantage of available shielding, distance, geometry, and other factors that affect the magnitude of the dose rate or the portions of the body exposed to the radiation.

(4) Photographs of "as installed" equipment or components can be valuable for planning purposes and can be augmented by additional photos taken during the surveys. The use of portable TV cameras with taping features has considerable merit as both an operational aid and a teaching aid.

(5) The existing radiation levels frequently can be reduced by draining, flushing, or other decontamination methods or by removing and transporting the component to a lower radiation zone. An estimate of the potential doses to station personnel expected to result from these procedures is germane in selecting among alternative actions.

(6) A preoperational briefing for personnel who will perform services in a high radiation area can ensure that service personnel understand the tasks about to be performed, the information to be disseminated, and the special instructions to be presented.

(7) A program can be implemented to provide access control and to limit exposures to those persons needed to perform the required services in the radiation areas. Such a program would address conditions that require a special work permit or other special procedures.

(8) A work permit form with an appropriate format can be useful for recording pertinent information concerning tasks to be performed in high radiation areas so that the information is amenable to cross-referencing and statistical analysis. Information of interest would include the following items:

(a) Designation of services to be performed on specific components, equipment, or systems;

(b) Number and identification of personnel working on the tasks;

(c) Anticipated radiation, airborne radioactive material, and contamination levels, based on current surveys of the work areas, and date of survey;

(d) Monitoring requirements such as continuous air monitoring or sampling equipment;

(e) Estimated exposure time required to complete the tasks and the estimated doses anticipated from the exposure;

(f) Special instructions and equipment to minimize the exposures of personnel to radiation and contamination;

(g) Protective clothing and equipment requirements;

(h) Personnel dosimetry requirements;

(i) Authorization to perform the tasks; and

(j) Actual exposure time, doses, and other information obtained during the operation.

(9) Consideration of potential accident situations or unusual occurrences (such as gross contamination leakage, pressure surges, fires, cuts, punctures, or wounds) and contingency planning can reduce the potential for such occurrences and enhance the capability for coping with the situations expeditiously if they occur.

(10) Portable or temporary shielding can reduce dose rate levels near "hot spots" and in the general area where the work is to be performed.

(11) Portable or temporary ventilation systems or contamination enclosures and expendable floor coverings can control the spread of contamination and limit the intake by workers through inhalation.

(12) "Dry runs" on mockup equipment can be useful for training personnel, identifying problems that can be encountered in the actual task situation, and selecting and qualifying special tools and procedures to reduce potential exposures of station personnel.

(13) Adequate auxiliary lighting and a comfortable environment (e.g., vortex tube coolers for supplied air suits) can increase the efficiency of the work and thus reduce the time spent in the higher radiation zones.

(14) Radiation monitoring instruments selected and made available in adequate quantities can permit accurate measurements and rapid evaluations of the radiation and contamination levels and changes in levels when they occur. Routine calibration of instruments with appropriate sources and testing can ensure operability and accuracy of measurements.

(15) Performing work on some components inside disposable tents or, for less complicated jobs, inside commercially available disposable clear plastic glove bags can limit the spread of contamination. Such measures can also avoid unnecessary doses resulting from the need to decontaminate areas to permit personnel access or to allow for entry with less restrictive protective clothing and equipment requirements.

(16) Careful scheduling of inspections and other tasks in high radiation areas can reduce exposures by permitting decay of radiation sources during the reactor shutdown period and by eliminating some repetitive surveys. Data from surveys and experience attained in previous operations and current survey data can be factored into the scheduling of specific tasks.

**b. Operations**

During operations in radiation areas, adequate supervision and radiation protection surveillance should be provided to ensure that the appropriate procedures are followed, that planned precautions are observed, and that all potential radiation hazards that might develop or that might be recognized during the operation are addressed in a timely and appropriate manner.

(1) Assigning a health physics (i.e., radiation safety or radiation protection) technician the responsibility for providing radiation protection surveillance for each shift operating crew can help ensure adequate radiation protection surveillance.

(2) Personnel monitoring equipment such as direct-reading dosimeters, alarming dosimeters, and personal dose rate meters can be used to provide early evaluation of doses to individuals and the assignment of those doses to specific operations (see Regulatory Guides 1.16, "Reporting of Operating Information—Appendix A Technical Specifications," and 8.4, "Direct-Reading and Indirect-Reading Pocket Dosimeters").

(3) Communication systems between personnel in high radiation zones and personnel who are monitoring the operation in other locations can permit timely exchanges of information and avoid unnecessary exposures to monitoring personnel.

**c. Postoperations**

Observations, experience, and data obtained during nonroutine operations in high radiation zones should be ascertained, recorded, and analyzed to identify deficiencies in the program and to provide the bases for revising procedures, modifying features, or making other adjustments that may reduce exposures during subsequent similar operations.

(1) Formal or informal postoperation debriefings of station personnel performing the services can provide valuable information concerning shortcomings in preoperational briefings, planning, procedures, special tools, and other factors that contributed to the cause of doses received during the operation.

(2) Dose data obtained during or subsequent to an operation can be recorded in a preselected manner as part of a "Radiation Work Permit" or similar program [see regulatory position 3.a(8)] so that the data are amenable to statistical analyses.

(3) Information concerning the cause of component failures that resulted in the need for servicing in high radiation areas can provide a basis for revising specifications on replacement equipment or for other modifications that can improve the component reliability. Such improvements can reduce the frequency of servicing and thus reduce attendant exposures.

(4) Information gained in operations can provide a basis for modifying equipment selection and design features of new facilities.

(5) Summaries of doses received by each category of maintenance activity can be reviewed periodically by upper management to compare the incremental reduction of doses with the cost of station modifications that could be made.

**4. Radiation Protection Facilities, Instrumentation, and Equipment**

A radiation protection staff with facilities, instrumentation, and protective equipment adequate to permit the staff to function efficiently is an important element in achieving an effective program to maintain occupational radiation exposures ALARA. The selection of instrumentation and other equipment and the quantities of such equipment provided for normal station operations should be adequate to meet the anticipated needs of the station during normal operations and during major outages that may require supplemental workers and extensive work in high radiation areas. (Accident situations are not considered in this guide.) Station design features and provisions should reflect the following considerations:

**a. Counting Room**

A low-radiation background counting room is needed to perform routine analyses on station samples containing radioactive material collected from air, wa-

ter, surfaces, and other sources. An adequately equipped counting room would include:

(1) Multichannel gamma pulse height analyzer (Regulatory Guide 5.9, "Specifications for Ge(Li) Spectroscopy Systems for Material Protection Measurements—Part 1: Data Acquisition Systems," provides guidance for selecting Ge(Li) spectroscopy systems);

(2) Low-background alpha-beta radiation proportional counter(s) or scintillation counter(s);

(3) End-window Geiger-Muller (G-M) counter(s); and

(4) A liquid scintillation counter for tritium analyses. Analyses of bioassay and environmental samples and whole-body counting (see Regulatory Guide 8.9, "Acceptable Concepts, Models, Equations, and Assumptions for a Bioassay Program") call for additional equipment and laboratory space if the analyses are performed by station personnel rather than by other specialists through contractual arrangements.

**b. Portable Instruments**

Portable instruments needed for measuring dose rates and radiation characteristics would include:

(1) Low-range (nominally 0 to 5 R per hour) ion chambers or G-M rate meters;

(2) High-range (0.1 to at least 500 R per hour) ion chambers;[7]

(3) Alpha scintillation or proportional count rate meters;

(4) Neutron dose equivalent rate meters;

(5) Air samplers for short-term use with particulate filters and iodine collection devices (such as activated charcoal cartridges); and

(6) Air monitors with continuous readout features.[7]

**c. Personnel Monitoring Instrumentation**

Personnel monitoring instrumentation selection should include consideration of:

(1) G-M 'Friskers" for detecting low levels of radioactive material;

(2) Direct-reading low-range (0 to 200 mR) and intermediate-range (0 to 1000 mR) pocket dosimeters (see Regulatory Guide 8.4);

(3) Alarm dosimeters;

(4) Film badges and/or thermoluminescent dosimeters (TLD);

(5) Hand and foot monitors; and

(6) Portal monitors.

**d. Protective Equipment**

Utility-supplied protective equipment selection should include consideration of :

(1) Anticontamination clothing and equipment that meet the requirements of ANSI Z-88.2 (Ref. 15) for use in atmospheres containing radioactive materials or the National Institute of Occupational Safety and Health's (NIOSH) "Certified Personal Protective Equipment List," and current supplements from DHEW/PHS (Ref. 16).

(2) Respiratory protective equipment, including a respirator fitting program that satisfies the guidance of Regulatory Guide 8.15 and NUREG-0041 (Ref. 8).

**e. Support Facilities**

Design features of radiation protection support facilities should include consideration of:

(1) A portable-instrument calibration area designed and located such that radiation in the calibration area will not interfere with low-level monitoring or counting systems;

(2) Personnel decontamination area (this facility should be located and designed to expedite rapid cleanup of personnel and should not be used as a multiple-purpose area or share ventilation with food-handling areas) with showers, basins, and installed "frisker" equipment;

(3) Facilities and equipment to clean, repair, and decontaminate personnel protective equipment, monitoring instruments, hand tools, electromechanical parts, or other material (highly contaminated tools or other equipment should not be decontaminated in the area used to clean respiratory equipment);

(4) Change rooms that (preferably) connect with the personnel decontamination area and a control station area equipped with sufficient lockers to accommodate permanent and contract maintenance workers who may be required during major outages;

(5) Control stations for entrance or exit of personnel into radiation- and contamination-controlled access areas of the station such as the personnel entrance to the containment buildings and the main entrance to the radwaste processing areas; these control stations also may be used as the control point for radioactive material movements throughout the station and for the storage of portable radiation survey equipment, signs, ropes, and respiratory protective equipment;

(6) Equipment to facilitate communication between all areas throughout the station; and

(7) Sufficient office space to accommodate the temporary and permanent radiation protection staff, permanent records, and technical literature.

[7] Variable alarm setpoint features on these instruments can be valuable in providing a warning when unexpected substantial changes in dose rate or air concentration occur.

## D. IMPLEMENTATION

The purpose of this section is to provide information to applicants and licensees regarding the NRC staff's plans for using this regulatory guide.

This guide reflects current NRC staff practice in license application reviews. Therefore, except in those cases in which the applicant proposes an acceptable alternative method for complying with specified portions of the Commission's regulations, the methods described herein are being and will continue to be used in the evaluation of submittals for construction permits and operating license applications until this guide is revised as a result of suggestions from the public or additional staff review.

At the operating license review stage, the radiation protection design presented in the applicant's final safety analysis report will be reviewed against regulatory position 2 of this guide and differences from the recommendations of the guide will be identified (particularly for plants designed before Regulatory Guide 8.8 was issued). However, no substantive design changes will be required at the operating license stage unless the design change can prevent substantial man-rem exposures that cannot be prevented by procedural measures and the design change is consistent with the cost-effectiveness principle of maintaining occupational radiation exposures ALARA.

Methods other than those set forth in this guide may be substituted for those stated herein, provided they satisfy the criterion "as low as is reasonably achievable" of paragraph 20.1(c) of 10 CFR Part 20.

## REFERENCES


1. Ad Hoc Committee of the National Council on Radiation Protection and Measurements, "Somatic Radiation Dose for the General Population," Science 131, 482 (1960).

2. "The Effects on Populations of Exposure to Low Levels of Ionizing Radiation," National Academy of Sciences/National Research Council, DHEW Contract PH-43-64-44, November 1972.

3. International Commission on Radiological Protection (ICRP), "Implications of Commission Recommendations That Doses Be Kept As Low As Readily Achievable," ICRP Publication 22, Pergamon Press, 1973. Copies may be obtained from Pergamon Press, Maxwell House, Fairview Park, Elmsford, New York 10523.

4. C. A. Pelletier et al., "Compilation and Analysis of Data on Occupational Radiation Exposure Experienced at Operating Nuclear Power Plants," Atomic Industrial Forum, 1974.

5. T. D. Murphy, N. J. Dayem, J. Stewart Bland, and W. J. Pasciak, "Occupational Radiation Exposure at Light-Water-Cooled Power Reactors, 1969-1975," NUREG-0109, U.S. Nuclear Regulatory Commission, August 1976. Copies may be obtained from the National Technical Information Service, Springfield, Va. 22161.

6. NUREG-0322, "Ninth Annual Occupational Radiation Exposure Report, 1976." Copies may be obtained from the National Technical Information Service, Springfield, Va. 22161.

7. ANSI N237, "Source Term Specification." Copies may be obtained from the American Nuclear Society, 555 North Kensington Avenue, La Grange Park, Illinois 60525.

8. Copies of NUREG-0041 may be obtained from the National Technical Information Service, Springfield, Va. 22161.

9. ANSI N101.2, "Protective Coatings (Paints) for Light Water Nuclear Reactor Containment Facilities." Copies may be obtained from the American National Standards Institute, 1430 Broadway, New York, N.Y. 10018.

10. ANS/HPS 56.8, "Location and Design Criteria for Area Radiation Monitoring Systems for LWRs," (draft).

11. ANS N197, "Design and Performance of BWR Liquid Radioactive Waste Processing Systems (N18)." Copies may be obtained from the American Nuclear Society, 555 North Kensington Avenue, La Grange Park, Illinois 60525.

12. ANS 55.1, "Design Criteria for the Solid Radwaste Processing System of BWR, PWR, and HTGR." Copies may be obtained from the American Nuclear Society, 555 North Kensington Avenue, La Grange Park, Illinois 60525.

13. ANS N199, "PWR Liquid Waste System Design (N18)." Copies may be obtained from the American Nuclear Society, 555 North Kensington Avenue, La Grange Park, Illinois 60525.

14. Section XI, ASME Boiler and Pressure Vessel Code and Addenda. Copies may be obtained from the American Society of Mechanical Engineers, United Engineering Center, 345 East 47th Street, New York, N.Y. 10017.

15. ANSI Z-88.2, "Practices for Respiratory Protection." Copies may be obtained from the American National Standards Institute, 1430 Broadway, New York, N.Y. 10018.

16. NIOSH, "Certified Personal Protective Equipment List," July 1974, and supplements by DHEW/PHS. Published by U.S. Department of Health, Education, and Welfare, Public Health Service, Center of Disease Control, National Institute of Occupational Safety and Health. Copies are available from the Office of Technical Publications, National Institute of Occupational Safety and Health, Post Office Building, Cincinnati, Ohio 45202.

# CHAPTER 5

# INSTRUMENTATION

5

# 5.0 INSTRUMENTATION

## 5.0.1 Purpose

Provide a brief overview of instruments used to detect and measure radiation levels and contamination.

## 5.0.2 Objectives

At the conclusion of this section, you should be able to:

- Summarize the advantages and disadvantages of the different types of devices used to monitor individuals for radiation exposure
- Describe the principal advantages and disadvantages of Geiger-Mueller (GM) type survey instruments
- Describe the principal advantages and disadvantages of Air Ionization Chamber type survey instruments
- Summarize the important characteristics of any radiation monitoring instrument and why these characteristics are important for obtaining accurate results
- Select the appropriate instrument for a particular task, be able to ensure its proper operation and be able to interpret the results obtained

## 5.1 Introduction

Radiation survey instrumentation operates on the principle of ionizations created by ionizing radiation in the detecting media. There are many instruments and devices for detecting and measuring radiation. To simplify matters, the devices can be divided into categories and the generic capabilities of each category described.

As noted in the above statement, instruments can perform two functions; they can detect radiation or they can measure radiation. Essentially, detection is the act of determining (real-time) whether radiation is present or not while measurement is the act of determining how much is or was present (if any).

Ideally, it would be best to detect and measure radiation simultaneously. However, as easy as it sounds, not all instruments can do both. Some only detect while others only measure and still others both detect and measure. Although it may seem odd that a device can measure radiation without detecting it, the key lies in the definition of detection which is limited to "real-time". Some devices measure radiation quite accurately but because of the manner in which the information is stored and retrieved, the information is only available some time later which makes it useless as a detector. As a result of the subtle distinction between these two functions, it's important to decide what is required and then select the instrument which performs the desired function.

## 5.2 Dosimetry

Dosimetry is a sub topic of instrumentation. Special devices are used to measure the amount of radiation to which an individual has been exposed and this information is used to insure compliance with federally imposed dose limits and to maintain an historical record of the individual's accumulated radiation dose.

Dosimetry itself is usually divided into two categories, external and internal.

External dosimetry is the action of determining the amount of radiation dose received by an individual from radiation sources located outside the body. External dosimetry is useful for monitoring doses from penetrating radiations such as x-rays, gamma rays and neutrons. It is also possible to monitor the dose to the skin surface from non-penetrating radiation such as beta. Alpha is of no concern to external dosimetry since alpha particles do not have sufficient energy to reach vital tissue

if incident on the surface of the body.

Internal dosimetry is the action of determining the amount of radiation dose received by an individual from radiation sources that have been taken into the body. The radiation emitted by the material exposes vital internal organs. In this case the relative hazards are directly opposite to those from external sources. Alpha particles, since they cannot escape from the body deposit all of their energy in vital tissues and are thus the most hazardous while penetrating x-rays or gamma radiation can easily escape and thus deposit only a small fraction of their energy in vital tissues. Betas are consistent in that they are both an external and an internal hazard since they have just enough energy to penetrate to sensitive skin tissuefrom the outside and also to expose vital tissues from the inside. Neutrons are not considered an internal hazard since there are almost no radioactive materials which spontaneously emit neutrons.

Internal dosimetry will be discussed in more detail in the chapter on Bioassay. This chapter will deal exclusively with external dosimetry sometimes called personnel dosimetry.

There are three basic tools used to perform personnel dosimetry:

- Pocket Dosimeters,
- Film Dosimeters, and
- Thermoluminescent Dosimeters (TLD's).

Dosimeters are small devices which are usually worn by a radiation worker somewhere between the neck and waist to monitor for radiation exposure to that portion of the body which contains most of the critical organs. In special cases, dosimeters may be used to monitor radiation exposure to specific portions of the body such as the extremities.

### 5.2.1 Pocket Dosimeters

Normally, personnel dosimetry is a method of "measuring" cumulative dose from beta, gamma and neutron radiation over an extended period of time such as 1 month. However, dosimetry can sometimes be used for the dual purpose of "detecting" the dose as it is being received (real-time) and also "measuring" how much was received. This is accomplished by "pocket dosimeters". Some pocket dosimeters are also called pocket chambers or pencil dosimeters.

Remember that dosimeters only measure accumulated dose. They do not directly indicate dose rate. Also, neutron dosimeters are commonly used only in those cases where neutron radiation is significant. Beta particles are not usually detectable by standard pocket dosimeters.

Pencil type pocket dosimeters (the most commonly used today) typically have a maximum range of 200 millirem, 500 millirem, 1 rem or 2 rem. Although not used in the nuclear industry, some dosimeters have ranges extending to 600 Roentgens.

There are three basic kinds of pocket dosimeters:

- Direct or Self Reading Dosimeters (DRD's or SRD's),
- Indirect Reading Dosimeters (IRD's), and
- Digital Alarming Dosimeters (DAD's).

#### 5.2.1.1 Direct Reading Dosimeters

These dosimeters are usually of the pencil design. The individual can read the dosimeter by peering through it like a mini-telescope while pointing it at a light. The light shines through a scale making it visible. The dose on such a dosimeter is indicated by a "hairline" which is in reality a thin wire loop which moves across the

illuminated scale. The hairline is initially set to zero by placing the dosimeter in a charging device which distributes similar electrical charges on the moving wire loop and on an identical fixed wire loop. The similar charges cause the mobile wire loop to be repelled and when fully charged, the loop appears superimposed over the zero position on the scale.

As the dosimeter is exposed to radiation, the radiation ionizes atoms which dissipates the charge causing the repulsive force between the two wire loops to decrease resulting in the mobile loop (the visible hairline) moving upward across the scale. If you don't see anything when you look through the dosimeter, the light may not be bright enough or you may be looking through the wrong end.

If a dosimeter with the correct scale is chosen, it can be extremely useful since it allows an individual to monitor his/her own dose at any time. Based on the dose indicated, the individual can decide when it's time to leave the radiation area.

### 5.2.1.2 Indirect Reading Dosimeters

Indirect reading dosimeters are similar to direct reading dosimeters except they can't be read without a charger/reader.

This type of dosimeter is not as useful as a DRD since without the reader device, workers can't monitor their dose as it is being received. They must wait until someone who has access to the reader evaluates their exposure. As a result, IRDs are seldom used. However, for short term results they are still better than film dosimeters or TLD's which are typically collected and processed once each month.

### 5.2.1.3 Digital Alarming Dosimeters

Digital alarming dosimeters (DAD's) indicate the accumulated dose using a digital display rather than an electrically charged wire loop. Some DAD's have LED displays which are normally blank. When a worker wants to see their current dose, they must press a button for the numbers to be displayed. These dosimeters do have one major advantage. They emit an audible signal ("beep") when a certain amount of radiation is detected.

Some of these dosimeters have an alarm which can be preset to trigger at some accumulated dose value such as 100 millirem. This is ideal since a worker would not even have to check his/her dosimeter. He/she can perform a task knowing that when his/her alarm sounds he/she can leave the area before exceeding a specified limit (provided the alarm works).

There are also devices called "beepers". These are NOT dosimeters. They are great for warning you of a radiation area but they only "beep", they do not accumulate dose. The faster the beeps, the higher the radiation levels, however, they cannot tell you how much dose you have received.

### 5.2.1.4 Pocket Dosimeter Characteristics

Pocket dosimeters are a tremendous asset to the radiation worker or anyone who might enter a radiation area (knowingly or unintentionally). However, they are not foolproof. The following are a few things to consider when using pocket dosimeters:

1. Range

Since pocket dosimeters have a specified range over which they are effective, it is important to know in advance the approximate maximum dose you are likely to receive to be able to select a dosimeter with an appropriate range. A 0 to 20 rem pencil dosimeter won't help you to measure a 100 millirem dose since the dose would likely be too low down on the scale, virtually unnoticeable. On the other hand a 0 to 200 millirem pencil dosimeter won't be of much use if your dose is 300 millirem. It will indicate off scale and you won't know what you've received.

A pocket dosimeter should indicate zero before it is issued. However, it is not critical if there

is a small dose already on it, as long as it's noted at the time it is issued. When you are finished with the dosimeter, the initial dose can be subtracted from the final dose to obtain the accumulated dose. However, a dosimeter isn't much use if the initial dose doesn't leave enough room on the scale to measure your expected dose. If a 200 millirem dosimeter has 80 millirem before it is issued to you, then you effectively have been issued a 120 millirem dosimeter which is the maximum it can accumulate before going off scale. When the dosimeter indicates about 3/4 of full scale (150 on a 200 millirem pencil dosimeter) it should be zeroed.

2. Fragility

Pocket dosimeters are susceptible to false readings. Since the pencil type dosimeters use a "hairline" filament to indicate dose, they are obviously fragile. If you drop them the "hairline" can move up or down scale. Also, because of optical, gravitational and other effects the pencil type dosimeter should always be read with the scale in its proper orientation (right side up not upside down or standing on end). Even with DAD's, the result of dropping a dosimeter may be unpredictable

3. Leakage

Since the operation of pocket dosimeters is based on electrical principles (charge, voltage, electrostatic repulsion, capacitance) they can be affected by charge leakage. However, the manner in which pencil dosimeters operate has one significant side benefit in that a defective dosimeter which is leaking charge will result in an upscale movement (i.e. a positive or conservative failure). This false positive reading may cause unnecessary concern, but, this is preferable to a false negative reading which could result in an overexposure. Fortunately, most significant leakage is fast enough so that if you check the dosimeter over a period of 15-30 minutes before going into a radiation area, you may be able to notice the upward drift.

4. Environment

Pocket dosimeters may also be susceptible to environmental conditions (e.g. humidity) particularly if it is of the ionization chamber type where the detection chamber is simply filled with air at atmospheric pressure.

Despite the potential problems, pocket dosimeters, in general, are useful and reliable devices. They are checked before they are issued. They undergo a physical inspection and a leakage check. They are also calibrated using a radiation source. All in all, it's the best device available to monitor your dose real-time.

### 5.2.2 Film Badges

A film badge is a device for measuring beta, gamma and neutron radiation by means of a piece of radiation sensitive film similar to x-ray film or photographic film. In fact, the film in some badges closely resembles dental x-ray film packets while others resemble 8 mm movie film strips.

Radiation striking the film causes atomic and molecular changes which when chemically developed cause the film to be darkened. Therefore, black means exposed and clear means not exposed and the density of the dark areas indicate how much radiation was received. Unlike direct reading pocket dosimeters, however, you don't know what radiation dose you have received until the film is developed (usually once a month).

Film badges are typically constructed of plastic to permit gamma radiation to penetrate to the film inside. However, the plastic would ordinarily prevent betas from being measured. To compensate for the poor penetrating ability of beta particles, an opening called a window is cut into the plastic over a small corner of the film. This opening permits measurement of both beta and gamma while the remainder of the film (under the plastic) is only able to measure gamma. Therefore an estimate of the beta contribution to the dose is

obtained by subtracting the results from the two sections of the film. Of course the film is enclosed in a light tight wrapper which prevents it from being exposed to light but is thin enough to permit betas to penetrate.

Film dosimeters are no longer extensively used for beta/gamma monitoring. However, they are still used by some for neutron dose measurements. Film dosimeters like pocket dosimeters only measure dose, not dose rate.

Film has one major advantage over all other radiation measuring methods. It produces a permanent image of the radiation exposure which can be kept almost indefinitely for future reference.

Like all photographic film, radiation monitoring film is sensitive to environmental conditions. Heat will "fog" the film making it appear to have been exposed to radiation. The film image will also "fade" if the film is not developed soon after use. Fading causes the images to become lighter meaning an underestimate of the dose.

Film also has a range problem. As the dose goes higher the film gets darker but at some point its going to be as black as it will ever get. It will be impossible to detect any difference if the film is exposed to more radiation which would underestimate very high doses. To compensate for this, some dosimeters may contain two types of film. A sensitive film measures doses in the lower range perhaps up to 500 millirem while the second, less sensitive film, is effective from about 500 millirem up to perhaps 100 rem.

Film uses silver which is a precious metal. Processing film is also costly and messy involving toxic chemicals.

### 5.2.3 Thermoluminescent Dosimeters

Thermoluminescent dosimeters (TLD's) have virtually replaced film as the method of measuring beta and gamma radiation dose. TLD's are crystals which have the ability to store information indicating how much radiation they were exposed to. The information is in the form of electrons which move to higher energy levels when exposed to radiation. The electrons remain trapped in those levels until the crystal is heated (hence the "Thermo" portion of TLD). The heat causes the electrons to fall back to their initial levels and when they do, stored energy in the form of light is emitted (hence the "luminescent" portion of TLD). The amount of light emitted during these transitions is proportional to the amount of radiation energy initially absorbed by the crystal.

The crystals can be in almost any form or shape and several different substances are commonly used as TLD material, but most radiation workers are issued lithium fluoride (LiF) or calcium fluoride (CaF) TLD's. Most of the LiF TLD's are in the form of small chips about 1/8 inches square. Badges with more than one crystal and various overlying filters can be used to assist in identifying the energy and type of radiation which caused the exposure. TLD badges like film badges are usually constructed of plastic with an open window to permit measurement of beta radiation.

TLDs have a wide range from a few millirem to hundreds of thousands of rem.

The information about the radiation exposure, once stored in the TLD, doesn't fade for long periods of time provided it is not heated beyond normal temperatures.

Because of their size, TLD monitors can be made very small which makes them useful for specialized applications. For example, a TLD chip can be placed inside a finger ring making a convenient extremity monitor. This would not be possible with film.

TLDs do not provide a permanent record. When a TLD is heated the result is a computer printout of the dose. Once a TLD has been processed, that's it, there's no going back for a second look.

### 5.2.4 General Dosimetry Rules

There are some very important rules which are applicable to all dosimeters:

- Don't forget to wear one when it is required,
- Don't forget to turn it in for evaluation when you exit the radiation area, and
- If you should lose your dosimeter while in a radiation area, or if your pocket dosimeter reads off scale, LEAVE THE AREA. As you leave, notify anyone in the area, particularly if your pocket dosimeter is off scale. They might wish to check their dosimeters to see if they are also off scale.

## 5.3 Instruments

There are many different kinds of instruments used to detect or monitor for radiation. Laboratory instruments, for example, are usually designed to be very sensitive. They're either used to measure very small amounts of radiation or are designed to measure some quantity very accurately. They also tend to be very big and expensive. Some examples are automated alpha/beta counting systems and alpha or gamma spectroscopy systems for evaluating environmental and biological samples. Another type of instrument includes those which are "transportable" but are difficult to move around. They typically do just one task (similar to a laboratory instrument) but can be transported to remote locations. This category includes instruments such as continuous air monitors (CAMs) and portable germanium gamma spectrometers.

### 5.3.1 Survey Meters

Survey meters are typically portable radiation detection instruments designed to be used in the field, under less than ideal conditions. As a result, they typically have an accuracy of $\pm$ 10 or 20%. Their principal function is to help you evaluate the current situation and allow you to make an intelligent decision based on the results.

Unlike laboratory instruments which usually perform only one specific task, portable instruments frequently are flexible. For example, depending on the probe attached to a meter, you might be able to detect alpha, beta, gamma or neutrons. Unfortunately, there is not currently a single instrument which will detect all of these simultaneously.

The two most common types of survey meters are ionization chambers and Geiger-Mueller (GM) instruments. However, there are others including plastic scintillators, zinc-sulfide and sodium-iodide crystals.

All such instruments, however, work on the same principle. In fact, all devices which respond to radiation do so by the principal of ionization. The radiation being detected or measured interacts with the atoms of a substance (gas, liquid or solid) and ionizes the material (i.e. creates free electrons and positive ions). In some cases, the ions are collected directly (e.g. GM detectors), while in others, the light emitted by the atoms as they return to their normal condition is measured (e.g. TLDs) or the light emitted is used to generate photoelectrons which are then collected (e.g. scintillation detectors).

#### 5.3.1.1 Applicability/Operability

Before taking any instrument into a radiation or contaminated area it is important to know whether the instrument works properly and does what you want it to do. To ensure that the instrument will perform as desired, the following items should be evaluated:

- Is it working,
- Will it detect/measure what I want to detect/measure, and

- Do I know how to use it?

If the answer to any of these questions is NO, there is obviously a problem. The following sections will address these and other important items.

1. Is It Working?

To ensure that an instrument is working you should check at least these five things:

a. Calibration

Before you do anything else, check to see if the instrument is calibrated. Each instrument will usually have a sticker somewhere which indicates when it was last calibrated and when it is due. If it is past the calibration due date, don't bother to do anything else. Get a new instrument. It should be remembered, however, that if an instrument is out of calibration, that doesn't automatically mean it is not working and conversely, if an instrument is in calibration, that doesn't automatically mean it is working.

b. Range

Check to see if the range on the instrument will cover the radiation or contamination levels you expect to encounter. If you expect to go into high radiation areas (exposure rates in excess of 100 mR/hr) a survey meter with a maximum range of 50 mR/hr won't do you any good. It will "detect" the radiation by pegging the display on the highest scale, but you won't know how much above 50 mR/hr it is. It could be 51 or it could be 50,000. All is not lost, however, since you can sometimes get a "feel" for how much radiation there is by observing how fast the needle "pegs" (assuming it is an analog meter and not digital). If the needle moves up scale slowly and just passes the maximum reading, it probably is not too much above 50 mR/hr. On the other hand, if the needle moves so fast that you only see a blur and the needle bends over double when it reaches the maximum value, it's time to beat a hasty retreat. Digital displays also provide some "feel" for the levels depending on how fast they reach the maximum value and start flashing an overrange indication. However, instruments with digital displays are much more difficult to interpret if they go off scale.

The above "interpolation" procedure is not recommended for routine evaluation of radiation levels. It is merely suggested as a means of determining how bad a situation is once you've gotten yourself into it. The best procedure is to use an instrument with the appropriate range and to approach potentially high radiation areas cautiously.

(1) Audible Signal

An instrument with too high a range can also cause problems. You could be in a radiation area of say 100 mR/hr and your analog meter might not even indicate it if full scale is 10 R/hr. Many instruments, however, provide you with something which compensates somewhat for an inappropriate scale range. They have an audible signal which alerts you to the presence of radiation. An audible signal is ideal for radiation detection because it's instantaneous. There's no delay as there is typically for a needle to respond or a digital display to update. You can sense how much radiation there is by the frequency of the beeps or the pitch of the audible signal. As long as the audible signal is independent of the meter movement it should continue to indicate the intensity of the radiation field irrespective of what the needle or display does. Remember, however, that beeps can only be so close together before they sound like a constant tone and pitch can only go so high before it's virtually inaudible. At that point, any increase in radiation level won't be noted even by the audible signal. You should have left long before it got that bad anyway.

(2) Units

You should also check to see if the scale on the meter is in the units you want to

measure (cpm, mR/hr etc). Usually a meter will have only one range on it's display but it may also have a knob which allows you to multiply the displayed range by some number to increase (or decrease) the indicated range. The meter may have a scale of 0-5 mR/hr and the multipliers may be factors of 10 such as 0.01, 0.1, 1, 10, 100, 1000 producing maximum scale values of 0.05 to 5,000 mR/hr. However, instead of multipliers, the instrument may indicate the maximum reading for the scale (e.g. a meter scale which displays 0-5 may have a selector switch which indicates 5, 50, 500 mR/hr and 5, 50 R/hr). It is up to you to determine the implied multiplier and interpolate for readings that are not full scale.

c. Physical Condition

You should perform a physical inspection of the instrument looking for obvious signs of damage or mistreatment. It is also wise to turn the instrument on and let it settle for a few minutes. This is particularly true if it has been stored in an environment different from where you intend to use it (e.g. if you left it overnight in the trunk of your car with the temperature at 30 degrees below zero and you plan on using it in a heated facility) since it might take a while for the instrument to adjust to this change in environment.

d. Battery

The battery condition should be checked prior to use. This is easily accomplished by selecting the battery test option and watching the needle on the meter climb into the "BATT OK" region or the digital display indicate an acceptable voltage. If you immediately assume that the batteries are OK, you may be making a mistake. Sometimes nearly dead batteries will build up enough charge when they're not used for awhile to give an initial surge of power but they soon become exhausted and fail. To avoid this problem, let the instrument stay in the battery check mode for about a minute to see if it is stable. If so, the batteries are good. If not, get new batteries. Also new batteries are recommended if the needle is on the very low end of the battery OK range or the digital display indicates marginal voltage.

e. Response to Radiation

If all other checks are successful, the only thing left to do is see if the instrument will detect radiation. After all, no matter what the condition of the instrument or batteries and no matter what the calibration sticker says, if it doesn't respond to radiation it isn't any good! To check if it responds, there is usually a small radioactive check source mounted somewhere inside or outside the instrument. If not, you may wish to request one. If you hold the detector near the source or turn a switch, you should get a response. If you're just going to look for radiation, that may be sufficient. However, if you want to accurately measure how much radiation there is, it would be useful to know if the check source indication matches the reading with the same check source at the time it was last calibrated. If it doesn't, the instrument may still be working but it may not give you accurate results. The check source reading at last calibration may be written on the calibration sticker.

2. Will I Detect/Measure What I Want to Detect/Measure?

It is a simple matter to look at the manufacturers information which accompanies the instrument to determine what it is capable of doing. If that information is not available you may want to ask someone if you have never used that particular instrument before. Basically you want to know:

a. Types of Radiation

Will it detect alpha, beta, gamma or neutrons (whichever you're interested in),

b. Energy Detected

What energies will it detect (most instruments have a low energy cut-off so that they will not detect radiation below a specified energy),

c. Energy Response

Ideally an instrument's response should be flat (i.e. independent of energy - what you see is what you get), however, some instruments do not have a flat response which means that for some energies a correction factor must be used to convert the instrument's meter reading to the actual radiation level. In addition, there are usually separate responses for radiation incident directly on the detector and for radiation which tries to sneak in through the side walls of the instrument. Needless to say, the response is usually much worse for the latter case.

d. Response Time

The response time indicates how fast the display will tell you what the actual radiation level is. A five second response time means that you won't know what the actual radiation levels are for the first 5 seconds that you are in the radiation field. Technically, you won't actually know the true exposure rate for several more seconds beyond that since the response is exponential and it only reaches about 90% of the actual value after 5 seconds. In reality, most instruments actually respond very quickly. In any case, 90% of final value is usually good enough to make a decision. Some instruments have quicker responses and some much slower. Some detectors even have variable response times which the user can select. Fast response gives you less accuracy while slow response gives you greater accuracy. You can select your own priority, speed or accuracy.

3. Do I Know How to Use It?

The answer to the third and final question is very simple. You either know how to use an instrument or you don't. A good time to learn is before you get into a radiation field.

### 5.3.1.2 Features

Besides all of the items discussed above there are a few more that the user of a survey instrument needs to be aware of:

1. Beta Discrimination

Many instruments have a moveable beta shield. This is simply a thick cover for the detector which, when used, prevents betas from being detected. With the beta shield closed the instrument is only detecting penetrating gamma radiation. With the beta shield open, the instrument detects both beta and gamma. By subtracting the two values you can determine approximately how much of the radiation field is due to beta. True beta dose, however, is very difficult to evaluate requiring a knowledge of the energy range of the betas and correction factors related to those energies. Unless one absolutely has to know the exact beta radiation dose, most people use a survey meter to "measure" gamma and merely "detect" the presence and relative magnitude of beta.

2. Battery Life

Typically, battery life expectancy is over 100 hours but that depends on the type of batteries you use, the temperature and whether the unit has any power draining options such as a lighted display. If its very cold or you frequently use the lighted display, the battery life may be greatly reduced.

3. Radiofrequency (RF)

RF sensitivity is a concern for some. If you have a microwave transmitter nearby, some instruments will give a false positive or erratic reading since the RF field affects the electronics. Most units are not sensitive to RF up to 20 milliwatts per square centimeter.

4. Electrical Fields

This is particularly a problem with air ionization type chambers. Since survey meters work by collecting electrical charges (positive and negative ions), if the instrument is used near a source of a strong electric field (such as a plastic

surface with static charge buildup), the instrument may indicate a positive response when, in fact, there is no radiation present.

5. Sensitivity

The sensitivity to particulate radiation such as alpha and beta is sometimes given as a percent. The sensitivity indicates what percentage of the particles actually emitted will be detected by the instrument. Since a radioactive source typically emits radiation in all directions (4 pi geometry or in a spherical configuration) most alpha/beta instruments will only be able to detect at most one half (50%) of the emissions (i.e. those particles being emitted towards the detector). The remainder simply do not interact with the detector. Such an instrument would thus have a maximum sensitivity of 50%. In reality the sensitivity would be much less since not all of the particles incident on the instrument will be detected.

### 5.3.2 GM Instruments

GM instruments are typically used to "detect" beta and gamma radiation. Therefore, they're used to "frisk" workers who are leaving contaminated areas and also used to detect surface contamination in work areas. They typically have scales with units of "counts per minute (cpm)". However, you may see some that have "mR/hr" scales. These instruments have usually been calibrated for exposure rate using a Cs-137 source. Since GM instruments do not have a flat energy response, the ability of the GM instrument to read exposure rate is limited to radiation with energy equivalent to that of Cs-137 (or whatever it was calibrated with). Any attempt to use the instrument to measure mR/hr for radiation of different energies or beta could result in a serious error.

A GM detector is typically a chamber filled with pressurized gas. The chamber is usually shaped like a cylinder with an opening either in the curved side of the cylinder or at the end of the tube. This is sometimes referred to as a "pickle" probe (for obvious reasons). GM detectors, however, can also be shaped like a flat disk at the end of a handle. This type is typically called a "pancake" probe (again for obvious reasons).

The principal advantages of a GM detector are its sensitivity and its rapid response while the principal disadvantages are its energy dependence and its tendency to saturate. Saturation was more common in older GM instruments but it is still prudent to be aware of this possibility. Saturation occurs when the GM instrument is used in a very high radiation field. Essentially, due to its sensitivity, it is overwhelmed and could possibly indicate no radiation (zero) when in fact the radiation levels are quite high. Newer instruments have what are called quenching materials mixed with the detection gas which should prevent saturation.

There are two common types of GM survey meters that NRC personnel may have the opportunity to use.

#### 5.3.2.1 Frisker

The first is a transportable GM survey meter such as an Eberline E-520. This unit has a detector probe which is connected to the meter by a cable which makes it convenient to detect radiation in difficult to reach locations. However, the instrument is usually placed on a flat surface and the item to be surveyed is brought to it. The cable permits movement of the probe around the object up to about 4 feet from the meter. This is a typical personnel frisker.

#### 5.3.2.2 Handheld

Another type of GM instrument is a "handheld" monitor such as a Xetex 305B. It is small enough to hold the entire instrument in one hand or small enough to fit in a shirt pocket. The detector is part of the meter housing so that wherever the detector goes, so does the display. That makes it difficult to use behind objects. The main advantages of handheld instruments are that they are compact, lightweight, easy to operate and inexpensive. The disadvantages are the small size of

the detector and the limited range.

### 5.3.3 Ionization Chambers

Ionization chambers are basically a box full of air. Radiation interacts with the air in the chamber by ionization, but the total number of ions produced is less than the number produced in the gas of a GM detector which is subjected to a higher voltage. That makes the ionization chamber less sensitive but more useful for "measuring" the radiation as opposed to just "detecting" it like the GM. Although not as sensitive, it's more accurate having a flat energy response. An ionization chamber calibrated with Cs-137 will accurately yield exposure rate measurements for a wide range of gamma energies while GM instruments calibrated with the same source may have energy correction factors of 5 or more. Ionization chambers normally are used for measuring beta and gamma radiation only.

NRC personnel are likely to use an ionization chamber similar to the Eberline RO-2. Actually there are two models, the RO-2 and RO-2A. The difference is that the 2A model has ranges which are 10 times higher than the model 2. The instrument has a sliding beta shield which can be used to screen out beta and look only at the gamma.

### 5.3.4 Teletector

This device is essentially a high range instrument for evaluating radiation levels without unnecessarily exposing the individual. It has a detector at the end of a pole which can be extended to about15 feet.

### 5.3.5 Displays

As noted throughout the previous discussions, survey instruments typically have two basic types of displays; analog (a needle pointing at numbers on a fixed scale) and digital (LED's or LCD's which flash the current value as a single number).

Some individuals don't like digital displays because they go blank and update every second or so. If you step into a high exposure field the display flashes on and off indicating a larger value each time. It seems to take forever for the display to reach the final value, but in reality the response time for most digital instruments is about the same as for analog ones. However, when you watch a needle move up scale it appears as if you're getting more information faster. Also when the needle reaches the actual value, say 50 mR/hr, it may fluctuate a little (say between 48 and 52) but the observer tends to average the fluctuations and select the middle value 50. On a digital unit, however, when the display jumps back and forth between 48 and 52 every second it confuses the user. Being digital, the user expects an exact number. However, the statistical variations make the user hesitate about selecting the final value (is it 48, no 51, no 49, no 52 and so on).

# CHAPTER 6

# BIOASSAY

6

# 6.0 BIOASSAY

## 6.0.1 Purpose

Provide a brief overview of the principles of bioassay including whole body counting and biological sampling to evaluate internal contamination.

## 6.0.2 Objectives

At the conclusion of this section, you should be able to:

- Describe the two different methods used for bioassay,
- Summarize the reasons for performing bioassay,
- Describe how radioactive material can enter and exit the body and how it is deposited in internal organs,
- Describe the principles of whole body counting and summarize the advantages and disadvantages of this method,
- Describe how biological sampling is employed to evaluate the amount of internal contamination and summarize the advantages and disadvantages of this method, and
- Summarize the basic principles of internal dosimetry including the concepts of Annual Limit on Intake (ALI) and committed dose.

## 6.1 Introduction

Bioassay implies the "ASSAY" or measurement of radioactive material in the body or "BIO"logical system. In reality, we don't measure the amount of radioactive material directly. We measure the amount of radiation emitted by the material and calculate how much radioactive material the radiation represents.

As discussed in Chapter 3, the objective in radiation protection is to minimize total radiation exposure (sum of external and internal exposure) and therefore total risk from radiation. In some cases, small intakes of radioactive material inside the body may occur in order to limit the total exposure. It is important to remember that, for the same amount of dose, the risk from external radiation is the same as that from internally deposited radioactive material. Bioassay is an important means for evaluating internally deposited radioactive material and, ultimately, the associated dose and the risks.

It is impossible to discuss bioassay without first discussing how radioactive materials get inside the body and then, of course, how they get back out again. Knowing how much radioactive material was taken into the body provides a means of evaluating compliance with federally imposed annual limits on intake. This information, however, is only useful because it allows us to determine the truly important quantity of interest, the dose. The dose is calculated from bioassay data using a process called Internal Dosimetry. From the dose we can then estimate the risk which is of ultimate concern to the individual.

## 6.2 Bioassay Techniques/Categories

Bioassay may be accomplished by either whole body counting or biological sampling.

Whole body counting, also known as direct or in-vivo measurement, is a method of determining the amount of radioactive material physically present in the body by detecting the penetrating radiation emitted from inside the body.

Biological sampling, also known as indirect or in-vitro measurement, is a method of determining how much radioactive material is in a sample collected from the body (e.g. urine) and then calculating how much radioactive material is actually in the body based on how much was in the

sample.

There are three basic categories of bioassay:

- Baseline - performed to determine if an individual has previously had radioactive material deposited internally,
- Routine - performed at regular intervals to determine if any radioactive material is being taken into the body during routine work activities. Routine bioassay may also be performed after specific tasks to determine the adequacy of protective measures, and
- Diagnostic - done when there is a known or suspected internal exposure. It is typically more detailed than a baseline or routine bioassay.

In addition to the three categories mentioned above, bioassay is also accomplished on a Random basis to spot-check radiation protection practices and also at Termination of employment to provide a final record.

## 6.3 Transport and Deposition of Radioactive Material Within the Body

Depending upon several factors such as mode of intake, chemical form, and solubility, radionuclides will move within the body, become distributed within various organs, and ultimately be eliminated through normal metabolic processes. During this process, they deliver an internal dose to the whole body and various organs.

### 6.3.1 Intake

Radioactive material can get inside the body by several different pathways:

- Inhalation,
- Ingestion,
- Absorption, and
- Injection.

The radioactive material entering the body through one or more of these pathways represents what is termed an "intake". Of the four pathways mentioned above, inhalation is, by far, the most common. Derived Air Concentrations (DACs) are designed to minimize inhalation of radioactive material.

### 6.3.2 Distribution

Once inside the body, however, radioactive material doesn't just sit there. Depending on how it behaves, e.g., its chemical properties, it moves around until it arrives at its preferred destination.

Inhaled radionuclides are divided into three classes depending on how they behave in the body. These classes are: Class D, Class W, and Class Y and are based on the time it takes them to be removed from the pulmonary region of the lung.Class D radionuclides are cleared within a matter of days (less than 10, the "D" represents days). Class W (for weeks) are cleared more slowly (from 10 to 100 days). Finally, Class Y (years) are cleared very slowly and may take years to be completely eliminated from the body (> 100 day). I-131 is a Class D radionuclide, whereas uranium oxide is an example of a Class Y radionuclide.

### 6.3.3 Uptake

Once radioactive material gets inside you, its final destination depends on the material (element and chemical form), its solubility and how it got inside you. The fact that a material is radioactive doesn't influence its movement in the body. Radioactive material behaves just as any other similar non-radioactive chemical compound.

In some cases, only a small fraction will get into the bloodstream and be carried to its final resting place. This is known as the "uptake", that

portion or fraction of the "intake" which is deposited in important regions of the body. That portion which is not taken up by the body is excreted (eliminated).

If the material was originally ingested (swallowed), much of it may pass through the GI system and be excreted in the feces although some may be absorbed into the bloodstream through the walls of the GI tract. If it was originally inhaled, some may stay in the lungs, some may be dissolved and transferred to the bloodstream and some will probably be cleared by ciliary action back up the trachea and then swallowed down the esophagus. Most of this part will then be cleared as if it was originally ingested. Needless to say, the movement of radioactive material inside the body is not as simple as implied above, but the above summarizes the major ideas.

### 6.3.4 Whole Body vs Individual Organ Dose

As discussed in section 6.3.3, different radionuclides behave differently inside the body depending on several factors such as solubility, transport within the body, clearance times from the lung, etc. This means that some radionuclides will be distributed more or less uniformly within the body and therefore result in uniform dose to the whole body, whereas other radionuclides will be preferentially deposited in specific organs.

Co-60 and Cs-137 are examples of radionuclides which give essentially uniform exposure to the whole body. In contrast, Sr-90 delivers a higher dose to the bone surfaces than to the whole body. I-125 and I-131 preferentially expose the thyroid.

### 6.3.5 Evaluating Internal Contamination

Once radioactive material gets inside the body (despite our best efforts), how do we estimate the seriousness of the problem? The answer is by whole body counting and biological sampling.

## 6.4 Whole Body Counting

Whole Body Counting is the direct measurement of internal radioactivity using organ counters or whole body counters.

Many different set ups or "geometries" are available to perform whole body counting. The individual being evaluated may be:

- Standing,
- Sitting, or
- Lying Down.

The amount of shielding surrounding the whole body counter will be a major contributor to the smallest amount of radioactive material detectable. The counting system may be:

- Open (unshielded),
- Partially Shielded, or
- Fully Shielded.

For some particularly sensitive low level whole body counting systems, pre-World War II battleship steel is used for shielding because it was manufactured from materials produced before nuclear weapons testing (1945-1963) contributed fallout to the environment and before Co-60 was used in blast furnaces as a tracer. Materials made after the war may have small amounts of built-in fallout (fission products) or tracer isotopes which would increase the background and reduce the ability to detect very small amounts of internal radionuclides.

### 6.4.1 Techniques

There are many ways that counting systems can be used to evaluate (and possibly localize) internal contamination:

- The detectors may be fixed in place with

the subject stationary, or

- The subject may be scanned by:

  Moving the detectors across the body, or

  Moving the body across the detectors

### 6.4.2 Counting Time

Counting times may vary from one minute fast scans to 30 minutes or longer. The longer the count, the smaller the amount of material detectable (sometimes called the minimum detectable activity [MDA]), but this must be balanced with the need for detecting small amounts. It should be remembered that the limits for internal contamination are not the same for all radioactive materials. The maximum amount of any radioactive material allowed by regulation will vary depending on type of material, location and radiation emitted. Therefore, the counting time will vary depending on the maximum amount allowed in the body.

For high energy gamma emitters (most fission products), counting times are short. For low energy emitters, counting times would have to be increased. Additional factors which influence counting times are, the economics of long count times, and, of course, the ability (or willingness) of the subject to stand, sit or lie still for long periods of time. Long count times are usually not necessary for routine evaluations, but may be necessary for diagnostic investigations.

### 6.4.3 Detectors

The detectors used for whole body counters are typically sodium-iodide crystals which have high efficiency but poor resolution or they may be germanium which has just the opposite characteristics, low efficiency but excellent resolution.

The two most important characteristics of any detector used for bioassay are:

- Efficiency - the ability to detect all of the radiation being emitted. This is important to determine how much activity is present (i.e. how many microcuries or nanocuries), and

- Resolution - the ability to distinguish between gamma rays having different energies. This is important since the detector distinguishes between different radioactive materials by looking at the energy of the radiation emitted by the materials. If different materials emit similar energies, the detector may not be able to tell them apart if the resolution is poor.

### 6.4.4 Organ Counter

An Organ Counter is basically the same as a whole body counter except that the detectors are focussed on specific organs where the radioactive material is likely to be located. Typical organs examined are lungs, liver, GI tract, bones and thyroid. Geometries and detectors are similar to those for whole body counters.

### 6.4.5 Specificity

Whole body counters can only detect penetrating radiation such as gamma radiation or x-rays. They cannot detect alpha or beta particles since these radiations cannot escape from inside the body. However, most alpha and beta emitters also emit gamma radiation. This allows whole body counters to detect radionuclides which are normally thought of as alpha emitters such as uranium, plutonium and americium.

As noted, whole body counters can detect gamma radiation. However, they are not selective. They cannot distinguish the origin of the radiation. Therefore, if a subject has external contamination on his/her clothing or skin, the whole body counter will detect it and report it, just as if it had come from inside the body. This will cause an overesti-

mate of the amount of internal radioactive material. Because of this potential problem, subjects are frequently requested to shower and change into "clean" hospital type "scrubs" or throwaway coveralls before counting. Less time consuming is a quick external scan with a portable survey meter, frisker or portal monitor before counting. In addition there are other "tricks" that can be used to distinguish between internal and external contamination. The most intensive precautions are usually reserved for known contamination incidents or for low level internal counting rather than routine monitoring.

### 6.4.6 Advantages/Disadvantages

Some of the advantages of whole body counting for determination of internal contamination are:

- Provides a rapid assessment of internal contamination,
- Can localize the site of deposition,
- Does not depend on the solubility or excretion rate, and
- The range of error is usually low.

Some of the disadvantages of whole body counting for determination of internal contamination are:

- Sensitive to external contamination,
- Primarily limited to gamma emitters above 100 keV, and
- Requires elaborate, complex and expensive equipment.

## 6.5 Biological Sampling

If all the material taken into the body stayed there, whole body counting would be the only way to evaluate the amount. Fortunately, such is not the case. What goes in, partially comes out.

### 6.5.1 Biological Elimination

Radioactive material may exit the body via several pathways in conjunction with these substances:

- Urine,
- Breath,
- Sputum,
- Blood,
- Nasal Mucous,
- Feces, and
- Sweat.

The rate at which radioactive material is removed from the body is very important. Only if it is predictable can it be used to evaluate the amount inside the body. Although not exactly predictable, it is predictable enough to be able to draw some conclusions about how much material remains inside.

### 6.5.2 Half Life

The radioactive material in the body is only hazardous if it remains there. Several factors which determine how long a material remains in the body are:

#### 6.5.2.1 Radiological Half Life

As discussed in section 1.3.3, it is the decay time unique to the radionuclide

#### 6.5.2.2 Biological Half Life

This is the time required for the body to eliminate one half of the material. This concept is not unique to radionuclides. All chemical substances are eliminated from the body with some biological half life. This concept provides the basis for drug testing. Radionuclides are chemicals just like drugs and they too will be eliminated from the body at some predictable decreasing rate.

### 6.5.2.3 Effective Half Life

This is a combination of the radiological and biological half lives. The actual value is equal to the product of the two divided by the sum. Some examples (based on fictitious numbers) are provided below:

| Radiological Half Life | Biological Half Life | Effective Half Life |
|---|---|---|
| 30 years | 100 years | 23 years |
| 8 days | 8 days | 4 days |

The existence of an effective half life implies that the material "disappears" exponentially. Unfortunately, this is not the case. The effective half life varies. The radiological half life never changes and the biological half life is relatively stable. The amount of material dissolved in bodily fluids and available for excretion in urine slowly decreases because it is being deposited in various organs where it is bound up and eliminated much more slowly. Therefore, instead of a straight line "effective disappearance" function we see an effective half life which is curved, gradually levelling off. This represents a combination of two exponential functions.

### 6.5.3 Excretion Rate

The excretion rate for radionuclides varies depending on several factors some of which have already been discussed:

- Radioactive material (radiological half life, chemical composition),
- Route of entry into the body,
- Time after intake,
- Organ in which the material is deposited, and
- Individual exposed.

The ability to predict what is happening stems from a knowledge of the first four factors. The last factor is truly unpredictable. Since every individual has a different metabolism, the excretion rate for two individuals would likely be different even if all of the other factors were identical. Because of this, excretion rates for a "reference" or "standard" man or woman are sometimes used to relate the amount excreted to the amount inside the body.

Under certain circumstances, the "normal" excretion rate can be accelerated to some degree. One simple way to increase elimination in the urine is to increase the intake of fluids. Another way to encourage elimination is by the administration of chemicals called chelating agents which bind with certain compounds such as heavy metals. The metals themselves, once they are bound to organ sites, would not normally be available for excretion. However, the chelating agent binds with the material, releasing it from the organ site. The radioactive material can then be excreted along with the chelating agent.

To summarize, the radionuclide is deposited in the critical organ and slowly eliminated. At the same time, the radioactive material also spontaneously decays.

### 6.5.4 Screening

Some biological sampling procedures are used for screening. A nasal smear is a good example. If there is a potential for inhalation of radioactive material, a cotton swab may be used to sample the inside of the nostrils. If the sample is negative, the results are not conclusive but may indicate a minor inhalation problem. If the results are positive, however, an inhalation incident is confirmed and additional bioassay should be done. Although a nasal smear is usually not used to measure the amount of intake, it can be used to estimate the magnitude of the intake.

### 6.5.5 Urinalysis

Of all the possible samples available for evalu-

ation, urine is the most common product of the human body collected for evaluation of possible intake of radioactive material. For some incidents involving ingestion, however, feces may be a better indicator of initial intake.

When urine sampling is performed, the subject is normally given very specific instruction on how to collect the sample. The procedure for doing this is usually dictated by the laboratory that will process the sample. It is absolutely imperative that the instructions be followed precisely. Typically a 24 hour urine sample is collected.

The frequency of collection depends on the Minimum Detectable Activity (MDA) of the analytical procedure, the probability of an intake and an estimate of the maximum amount of any possible intake.

Although some samples may be processed on-site, particularly if the radiation emissions involve only high energy gamma or beta, other samples may be sent to a remote laboratory for processing. Many contractor processing laboratories are available for complex analyses. Depending on the type of radiation to be detected, the sample is chemically processed and sent to the radiocounting facility which uses laboratory counting instruments for low level detection of gamma, beta and alpha.

Radiochemical processing and radiocounting can be very time consuming so that the frequency for biological sampling is chosen very carefully to provide the maximum assurance of identifying an internal contamination incident as early as possible while not taxing the analytical capabilities too extensively.

Some of the advantages of urinalysis for determination of internal contamination are:

- Most radionuclides are eliminated to some extent,
- Alpha, beta and gamma emitters can be readily identified,
- Many samples can be processed simultaneously,
- Collecting urine samples has a minimum impact on workers time, and
- Biological sampling involves low cost.

Some of the disadvantages of urinalysis for determination of internal contamination are:

- There is a time lag between the sample collection and analysis,
- There must be enough radionuclide in the sample to be detected,
- Analytical procedures are time consuming,
- Excretion rates vary with individuals and with time,
- Insoluble particles may not be excreted, and
- The individual may not follow instructions.

## 6.6 Dose Assessment

The hazards of internally deposited radionuclides depend on the:

- Amount of material,
- Effective half life and class,
- Portion or the body most irradiated, and
- Energy and Type of Radiation.

### 6.6.1 Acute/Chronic Exposure

Internal exposure can be divided into two

categories:

- acute exposure - any intake of radioactive material resulting from a single event (not necessarily instantaneously). After a single intake, the dose rate rises to a peak and gradually decreases due to radiological decay and biological elimination of the material. The rate at which it drops off will depend on how fast the material decays and how fast it is eliminated, and

- chronic exposure - any intake (usually at a low rate) which occurs continuously or periodically over a long period of time (long means days to years). Under normal circumstances, internal exposures, if they occur at all, are usually chronic and small. For chronic exposures, a gradual intake of material does not necessarily result in a steadily increasing dose rate. The dose rate depends on the rate at which the body is taking in the material and the rate at which the material is decaying and being eliminated.

If the material has a long effective half life (say several hundred years), then as long as more is coming into the body, the amount in the body would likely increase and the dose rate would steadily climb. As a result, even a slow chronic intake could eventually exceed a sharp acute intake if the time interval over which the material was being taken in was long enough and the sampling frequency was not often enough to detect it early.

This emphasizes the importance of a routine surveillance (bioassay) program. No matter how frequently samples are collected or whole body counts scheduled, a bioassay program cannot prevent an acute exposure. It just happens too fast. The only advantage to frequent sampling if an acute exposure occurs is that it will be discovered sooner, there will be a better chance of estimating how big it really was and there still may be time to give the exposed individual some medical treatment.

A good bioassay program, however, can keep a chronic exposure from becoming a serious problem by detecting the intake early (just as it exceeds the MDA) and stopping any additional intake.

### 6.6.2 Annual Limit on Intake (ALI) and 50-year Integrated Dose

When an individual is internally exposed to radioactive material, the risk to that individual is related to the radiation dose they will receive. Obviously, they will be exposed for some extended period of time depending on the effective half life.

Each year (assuming a relatively long half life) the dose is received will be less and less as the material is eliminated from the body and decays. However, it is difficult to calculate the changing dose each year. It is much easier to calculate how much total dose will result from the time of intake until all the material completely disappears. This latter procedure is used and the result is called the total integrated dose. That is, once the radioactive material is taken into the body, the individual is committed to receiving a certain dose from it. That total integrated dose is assigned to the individual even though she/he may not receive it for many years to come.

Since some materials with long effective half lives would remain in the body for hundreds of years or more, it isn't fair to assign the total integrated dose since the individual will no longer be alive. For this reason, a standard time interval of 50 years is used for conducting integrated dose determination. The dose to be received over the next 50 years after intake (called the 50-year integrated dose) is assigned in the year the radioactive material was taken into the body.

Calculating the 50-year integrated dose is not too difficult but the real problem is estimating

the time and amount of intake. If there is a specific incident which causes an exposure, then it is obvious when it happened. However, suppose there is no accident and sampling is only done once per year. It would be impossible to determine if the material was taken into the body in one event or gradually over time. If a bioassay result is found to be positive, an investigation can be conducted in an attempt to determine when the intake occurred, but if the investigation fails to find the cause, there is no alternative but to assume that the intake occurred right after the last negative result.

Although this is a conservative assumption, it may grossly overestimate the actual 50-year integrated dose since the exposure may have taken place the day before the positive result was determined. Since a large part of the dose is received during the time period immediately after the intake, the unknown time interval from the last negative result to the first positive result can be extremely important in estimating the 50-year integrated dose.

The 50-year integrated dose to an individual from intake of radioactive materials is limited by the Federally mandated Annual Limit on Intake (ALI), in microcuries. Whole body (stochastic) or organ-specific (non-stochastic) ALIs were derived for ingestion or inhalation of radioactive material to limit the 50-year integrated dose to the whole body to 5 rem per year or 50 rem per year to the maximally exposed organ. For example, intake by inhalation of Cs-137, which distributes uniformly in the body, is limited by its whole-body ALI of 200 microcuries. An intake of 200 microcuries of Cs-137 would result in a 50-year integrated dose to the whole body of 5 rem. Intake by inhalation of I-131, which seeks the thyroid, is limited by its organ-specific ALI of 50 microcuries. An intake of 50 microcuries of I-131 would result in a 50-year integrated dose to the thyroid of 50 rem.

Of course, if the individual has any external exposure, the allowable intake of radioactive material must be reduced by that amount so that the total radiation dose in a year does not exceed 5 rem to the whole body or 50 rem to any organ.

ALIs for ingestion and inhalation are listed in Table 1 of Appendix B to 10 CFR Part 20. For radionuclides which distribute uniformly in the body, only the whole-body ALI is listed in the table. For radionuclides which seek out a particular organ, the organ-specific ALI is more limiting. In this case, it is listed first and the organ on which it is based is listed directly beneath. The whole-body ALI is then listed in parentheses under the organ.

# CHAPTER 7

# PERSONNEL DECONTAMINATION

7

# 7.0 PERSONNEL DECONTAMINATION

## 7.0.1 Purpose

Provide an understanding of the importance of personnel decontamination and the techniques used to remove contamination from personnel.

## 7.0.2 Objectives

At the end of this lesson, participants should be able to discuss:

- Three goals of personnel decontamination,
- Contamination determination methods, and
- Personnel decontamination techniques.

## 7.1 Introduction

The objectives of personnel decontamination are to:

- Reduce exposure,
- Minimize intake of contaminants, and
- Prevent contamination spread.

Radioactive contamination on personnel is most often detected during the required whole body survey conducted when leaving a known or potentially contaminated area. Personnel contamination may also be detected during "spot" or local body area surveys conducted when leaving an area with a low potential for contamination. Spot and local area surveys are primarily used to survey body areas most likely to become contaminated.

Personnel survey is usually accomplished with sensitive GM detectors instruments, including:

- Hand held frisker probes,
- Automated personnel monitors,
- Hand and foot monitors, and
- Portal monitors.

When using a hand held frisker, pay particular attention to feet, exposed skin areas (viz., face, hair, hands), and chest. These areas are considered the most likely to be contaminated.

### 7.1.1 Action If Contamination is Detected

Personnel survey units are usually set to alarm at about twice the background count level (about 100 counts per minute above background for friskers in low background areas). When a unit alarms, follow the site procedure (usually standby for health physics). DO NOT SPREAD CONTAMINATION

### 7.1.2 Evaluation

Health physics will conduct a whole body survey to determine the contamination location(s) and level(s).

Wipes, shield techniques, and other instruments may be used to determine radiation type(s) and radionuclide(s) present. A whole body count may be used to assist in radionuclide identification.

## 7.2 Decontamination of Widespread or General Contamination

Shower with mild soap and tepid water. Keep radioactivity out of the eyes, nose and mouth and avoid spreading the material to any clean area of the body. Use copious water but do not shower for longer than a few minutes.

Dry thoroughly by patting skin with soft towel and repeat the survey. If contamination still exists, repeat the above actions at least 2 or 3 times. A soft bristle brush can be used to facilitate the decontamination effort, but it should be used sparingly.

Note: Do **NOT** break the protective skin barrier through excessive scrubbing.

## 7.3 Decontamination of Localized Contamination

For contamination in the eyes, mouth, or open wound, flush the area freely with water or normal saline solution. A physician should be contacted immediately.

If the contamination is in the nose or inhalation of radioactivity is suspected, blow your nose gently several times, being careful to not inhale through your nose. Wet cotton swabs may be used (by physician or the individual) to monitor for contamination and to decontaminate nasal passages. If the decontamination effort is unsuccessful, medical techniques, such as nasal irrigation, may have to be performed (by a physician).

Hair decontamination is initially attempted by washing several times with soap and water. Dry the head thoroughly after each washing and resurvey. If, after several attempts, contamination levels have not been reduced to acceptable levels, a medical technician physician should trim the hair and begin appropriate skin decontamination methods.

Decontamination of skin areas is accomplished by the following sequence of methods:

- Begin with mild soap and tepid water washing. Scrubbing should be performed carefully to not abrade the skin,
- Try a mild paste such as a mixture of 50% detergent (Tide, for example) and 50% cornmeal. Commercial decontamination foams or regular shaving foam may be useful,
- The above two techniques should be attempted three to four times before proceeding to the next method,
- A chemical agent such as potassium permanganate is usually the next step. Applied to the skin, it removes a small portion of the epidermis and should never be applied to the skin for greater than two minutes. After treatment, the permanganate is decolorized with a solution of sodium bisulfite and the area rinsed with water. Chemical decontamination methods should always be conducted under the control of medical personnel,
- Decontamination may be accomplished by sweating. Wrapping the affected area in plastic or rubber enhances sweating. Cotton or other absorbent should be used inside the plastic to collect the contamination,
- Decontamination by waiting for the radioactivity to decay away is used when the radioactive half-life is sufficiently short to permit decontamination in about 30 minutes, and
- Swabs, wipes, adsorbents and decontamination residues should be analyzed for radioactivity identification.

## 7.4 Decontamination of Clothing

Articles of personal clothing may become contaminated. To minimize the chance of clothing contamination avoiding the use of polyester (synthetic) clothing which tends to electrostatically attract radioactive particles and shoes with soft, spongy soles.

If contamination is from short-lived radionuclides, waiting for the contamination to decay may

be the best "decontamination" procedure.

If the wait for decay is not acceptable, the contamination may be removed by tape applied to the affected area(s), scrubbing clothing with soap and water, or by excising the affected area of clothing.

If decontamination is unsuccessful, the contaminated clothing is discarded through proper radioactive waste disposal methods.

## 7.5 Decontamination of Work Materials

Work materials and articles such as tools, notebooks, and instruments may become contaminated, although they are usually required to be in plastic bags while inside the controlled area to prevent contamination.

Survey procedures for removal of work materials from contaminated or potentially contaminated areas vary among facilities, but usually a licensee technician must conduct the survey. Make sure you know the site procedure.

Contaminated work materials are decontaminated using techniques similar to those used for clothing. However, inexpensive materials may be disposed of as radioactive waste to avoid the expense of decontamination while expensive or vital materials may undergo chemical, ultrasonic, or abrasion decontamination.

Items which can not be decontaminated and items frequently needed in contaminated areas are often uniquely marked and held inside controlled tool and material areas for future use.

# CHAPTER 8

# USE OF PROTECTIVE CLOTHING

# 8.0 USE OF PROTECTIVE CLOTHING

## 8.0.1 Purpose

Provide instruction, demonstration, and practice exercise of the proper techniques for donning and removing protective clothing, including proper actions while inside a radiological controlled area and the follow-up actions after removal of protective clothing.

## 8.0.2 Objectives

At the end of this chapter, course participants should be able to describe or demonstrate:

- Purpose of protective clothing,
- Protective clothing items and how to select,
- Proper techniques for donning and removing protective clothing, and
- Actions normally required after removal of protective clothing.

## 8.1 Purpose of Protective Clothing

The purpose of protective clothing is to:

- Prevent personnel external contamination,
- Reduce possibility of personnel internal contamination, and
- Reduce external radiation exposure (primarily from beta radiation).

## 8.2 Donning Protective Clothing

This discussion assumes that a set of protective clothing consists of:

- Coveralls,
- Shoe covers (flimsies),
- Rubber overshoes,
- Inner cotton gloves (glove liners),
- Outer rubber gloves,
- "Surgeon" or skull cap,
- Cloth hood, and
- (Safety glasses, ear plugs and other specified industrial safety equipment).

Practices for donning protective clothing may vary from one facility to another and depend on the type of protective clothing utilized, the protective clothing required, and the levels of contamination. Protective clothing requirements are set by the Health Physics manager. Learn the site specific rules and regulations before you enter any area requiring protective clothing (may be called PCs, anti-contamination clothing or anti-Cs). Figure 8-1 lists typical factors to be considered and steps to be accomplished in use of protective clothing.

NOTE: Entry into a radiologically controlled area is **NOT** permitted with any injury which exposes live tissue (i.e., cut, skin abrasion, wound) without prior approval from health physics and the injury protected as specified by health physics.

### 8.2.1 Prior to Donning Clothing

Study the Radiation Work Permit (RWP) to determine the proper clothing requirements for the job assignment and make sure you have the required dosimeters.

Select clothing large enough that it can be removed easily, but not so large as to encumber movement or to be unsafe; check each item for tears, holes, or split seams.

Check for pinhole leaks in rubber/plastic gloves by holding the glove open, squeezing off the wrist end, and forcing the trapped air into the palm and fingers.

Removal of outer clothing, jewelry, and other personal items is a normal routine at some sites (depends on contamination levels and site policies). Some, but **not** all, sites provide "modesty clothing" when removal of regular clothing is required. It may be wise to limit personal items taken to the site to those you are willing to leave in the custody of others and to dress in clothes that simplify the protective clothing routines.

Determine if dosimeters are to be worn inside or outside of protective clothing and bag dosimetry if necessary.

Prepare tape pieces to use for taping seams; fold tape over at ends to simplify for use and removal.

### 8.2.2 Donning Clothing

There is usually no specified sequence for dressing. However, a good sequence is to start with the inner or flimsy shoe covers and then proceed, in order, through; coveralls, rubber overshoes, tape ankles, safety glasses, cap, hood, dosimeters, tape coveralls, cotton inner gloves, rubber gloves, and tape wrists. Most workers save the rubber gloves and taping of wrist until last due to the inconvenience of working with the gloves.

Make a final check of yourself to ensure you are correctly suited and have all necessary dosimeters/tools/material.

### 8.2.3 Removing Clothing

Removal sequence is usually specified by the facility and requires first removing items most likely to be contaminated (e.g., overshoes, hood, rubber gloves). Make sure you know the facility procedures and follow the step-off-pad requirements. (See Figure 8-1, part 5 for a removal sequence).

Step-off-pads are used by facilities to help maintain contamination control. Step-off-pad rules of use generally prohibit stepping on them until specified items of protective clothing have been removed or until surveys for contamination have been completed.

Remove tape and protective clothing slowly and carefully to prevent spread of contamination. Promptly, but carefully, place removed items in their proper holding location or disposal container.

Remove dosimeters and handle as instructed (another procedure which varies among facilities from leaving them at the control point to taking them with you).

Be especially careful about what you touch after removal of the rubber gloves because the cotton glove liners provide very little contamination protection. The glove liners are primarily used to absorb perspiration and to facilitate removal of the rubber gloves. They provide the least amount of protection of any of the protective clothing items.

If you make an error in sequence or possibly cause cross contamination, immediately stay as still as you can and call for health physics assistance.

After removal of all protective clothing, follow instructions for whole body monitoring. This may be done with automatic personnel "portal" monitors, "frisker" booth units or hand held "frisker" probes.

Hand units require about 3 minutes for a complete frisk. Always check your hand for contamination before touching the frisker probe. Make sure the frisker unit is on and appears to be working properly with an audio response. Listen to the response and view the instrument meter while frisking. Keep the probe about 1/2 inch from your body and move it at a smooth rate of about 2

inches per second. Repeat the check of your hands for contamination after you are finished with the frisker.

The automated units have posted instructions and displays which light to inform you of the next step or a problem.

If the contamination monitor/frisker alarms, stay still:

- Look for posted instructions and follow them or the instructions provided during site specific training, and
- If no instructions are provided, call for health physics assistance.

When the whole body frisk is completed:

- Obtain your dosimeters and materials you need that were in the controlled area. Check the reading on your self-reading dosimeter, and
- Complete the sign-out and recording requirement for the RWP and Dose Card or other exposure record.

1) Proper Sign-In Procedure for RWP Area Entry:

A. Legible Signature,
B. Craft, Section and Date Correct,
C. Correct Time, e.g., Eastern/Military Used,
D. Dosimeter Reading.

2) RWP Requirements Satisfied to Enter Work Area:

A. Required Instruments Checked and Bagged,
B. Tools and Equipment Prepared.

3) Donning Protective Clothing Properly:

A. Inspect Gloves,
B. Inspect Protective Clothing,
C. Place Dosimetry in Coveralls,
D. Tape and Tab all openings

4) Performance in Work Area:

A. Knowledge of Work Area Radiation Levels,
B. Knowledge of Work Area Contamination Levels,
C. Monitor Dose Rates,
D. Read Pocket Dosimeter.

5) Removal of Protective Clothing:

A. Remove Tape,
B. Overshoes,
C. Hood,
D. Rubber Gloves,
E. Dosimetry,
F. Coveralls,
G. Booties and cotton inserts.

6) Personnel Contamination Survey:

A. Verify Settings on Frisker
B. Monitor Hands Prior to Picking up Probe,
C. Monitor Head, Face & Neck Areas,
D. Check Body, Arms & Legs,
E. Remain Alert for Increased Frisker Reading,
F. Monitor Dosimetry.

7) Proper Sign-Out Procedure for Exiting an RWP Area:

A. Document Reading on RWP,
B. Correct Reading of PC.

Figure 8-1 Requirements for Work in a Contaminated Area.

# CHAPTER 9

# INDUSTRIAL SAFETY

# 9.0 INDUSTRIAL SAFETY

## 9.0.1 Purpose

Provide a general overview of industrial safety practices at nuclear power stations and fuel cycle facilities.

## 9.0.2 Objectives

At the conclusion of this topic, course participants should be able to:

- Identify basic chemical hazards that might be encountered and the importance of the MSDS,
- Briefly describe other hazards that might be encountered such as heat stress, noise, and oxygen limited environments,
- Discuss general safety practices for the above hazards,
- Name basic industrial safety equipment and identify industrial safety items routinely required at nuclear power plants and fuel cycle facilities, and
- Explain the significance of the NRC's MOU with OSHA.

## 9.0.3 References

- "Hazard Communication Program" booklet published by Kramer Communication, 312 90th St., Daly City, CA 94015-1898
- Parts 1910 and 1926 of Title 29 of the Code of Federal Regulations

## 9.1 Introduction

Safety is everything we do to prevent accidents and is required for unescorted as well as escorted access. Each individual has the responsibility to read, understand, and follow the licensee's safety rules.

A nuclear power plant or fuel cycle facility is a very safe facility in which to work. However, a large number of potential hazards, other than those associated with radioactivity, do exist and the visitor to such a facility should be aware of the hazards. A summary of some of the more significant potential hazards that may be encountered at a nuclear power plant or fuel cycle facility is provided below.

## 9.2 Chemical Hazards

A wide variety of chemicals may be encountered at a nuclear power plant or fuel cycle facility. The Occupational Safety and Health Administration (OSHA) requires employers to inform employees of the safety and health hazards associated with the use of hazardous chemicals in the workplace (29 CFR 1910.1200).

Employers (licensees) are required to maintain Material Safety Data Sheets (MSDS) for all chemical hazards used in their workplace. An MSDS lists the safety precautions to be used when working around a specific chemical. If your inspection involves potential exposure to any chemical hazard with which you are unfamiliar, you should study the MSDS for the chemical before you are potentially exposed. A sample MSDS is provided in Figure 9-1.

The following descriptions summarize types of hazardous chemicals, examples of each, and basic protective guidelines.

### 9.2.1 Carcinogens

Carcinogens are substances that cause cancer. Only a very limited number of substances have been defined as carcinogens by OSHA.

Examples of carcinogens are benzidine, inorganic arsenic, and formaldehyde, which may be encountered in a chemical laboratory and asbestos

may be encountered with high temperature insulation.

Safe use depends on the particular chemical but in general care should be taken to avoid contact, inhalation, and ingestion.

### 9.2.2 Corrosives

Corrosives are chemicals that react with sufficient vigor to cause severe injury to living tissue.

Examples are many solvents, sodium hydroxide, and sulfuric and nitric acid which may be encountered in a chemical laboratory and in corrosive material lockers. Nitric acid and hydrogen fluoride are used at uranium conversion plants. Nitric acid and ammounium hydroxide are used at fuel fabrication facilities.

Safe use is to avoid direct contact with tissue. This can be accomplished by the use of protective gear (gloves, etc.) and proper containment of corrosives.

### 9.2.3 Explosives

Explosives are chemical substances that rapidly react to produce gases at sufficient temperature and pressure to cause damage.

Examples of explosives are hydrogen which is used to cool turbine generators at power plants and propane used for welding operations. Hydrogen, from the dissociation of water, may be present around the BWR main condensers. Hydrogen is used to reduce uranium oxides at fuel cycle facilities and it is also used in uranium pellet sintering operations.

Safe use is to prevent buildup to explosive concentrations and avoid use of sparking tools or electrical circuits in potentially explosive environments.

### 9.2.4 Gases

A gas is a substance in a physical state that will diffuse to fill a confining space. Gases may be hazardous as poisons, flammables, explosives, corrosives, or by simply displacing air and creating a suffocating environment.

Examples are nitrogen which is used as an inert purge and as an operation gas for some components and hydrogen, which is discussed above. At conversion plants, hydrogen fluoride (vaporized) is used to produce uranium tetrafluoride. Uranium hexafluride (a solid at room temperatures) is heated to a gaseous state for movement and chemical conversion at fuel cycle facilities.

Safe use depends upon the particular gas, but in general is to highly ventilate any area where gases are used, to wear air supplied breathing equipment, and to be especially aware of confined areas that may contain hazardous atmospheres. Since gases may be suffocating, explosive or corrosive, the safety practices for those conditions are applicable.

### 9.2.5 Poisons

Poisons are chemicals likely to cause death or serious injury if swallowed, inhaled, or in contact with the skin.

Examples are ammonia and chlorine used to treat cooling water and added to some reactor coolant treatment systems and carbon monoxide which can be generated by the running diesel generators and released by fire fighting systems. At fuel cycle facilities, cracked ammonia is used to reduce uranium compounds to uranium dioxide. Uranium conversion plants also use fluorine to produce uranium hexafluoride. Nitrous oxides are byproducts of dissolution processes in fuel cycle facilities.

Safe use is to avoid contact and properly contain all poisonous materials.

### 9.2.6 Solvents

Solvents are used to dissolve materials and may present several different hazards, such as toxicity, corrosiveness, or flammability.

Examples include general purpose cleaning fluids and degreasers and specific chemicals such as acetone, methyl chloroform, perchloroethylene, toluene, carbon tetrachloride which may be found in cleaning supplies, maintenance areas and inside plant auxiliary equipment spaces. Solvents such as hexane, dodecane and tributal phosphate are used in extraction processes at fuel cycle facilities.

Safe use is to ensure the area is well ventilated, minimize or limit prolonged exposure to fumes or to the skin, and to wear respiratory protection when advised (and if properly qualified).

### 9.2.7 Pyrophoric Metals

Pyrophoric metals are capable of igniting spontaneously when exposed to air, especially in a finely divided form.

Examples are uranium oxide powders used to make fuel pellets; and zirconium, magnesium or titanium alloys that are machined and fabricated into fuel rod cladding and other reactor components.

Safe use is to limit the amount of pyrophoric metals handled, minimize exposure to heat and air and remove combustible materials from process areas.

## 9.3 Live Steam and Hot Liquids

Live (hot and under pressure) steam and hot liquids can cause severe injury from burns, cutting, and by causing flying fragments. Serious burns can occur from touching uncovered steam and hot liquid pipes and components. Burns from hot components are one of the most frequent causes of injury or treatment at nuclear power plants.

Many piping systems in the reactor, auxiliary, and turbine building contain live steam or hot liquids. Main steam lines, condensers and heat exchangers, radioactive waste processing, reactor coolant sample stations, and seal and drain lines are just a few examples. Steam is also used to supply heat to chemical conversion processes at fuel cycle facilities and to vaporize uranium hexafluoride.

Safety around live steam and hot liquid piping systems is best accomplished by staying away from piping systems. Avoid touching any piping system or component unless necessary for your assignment and you are sure it is not hot.

## 9.4 Heat Stress

Some areas of nuclear power plants and fuel cycle facilities may have high heat and humidity levels due to operating equipment, steam lines, and limited ventilation due to shielding or containment designs. High heat and humidity are the principle components which may result in heat stress to personnel. Individuals unaccustomed to such conditions are particularly susceptible.

### 9.4.1 Common Heat Illnesses and Symptoms

Some common heat related illnesses and their symptoms are:

- Heat cramps - painful spasms of muscles,
- Heat exhaustion - fatigue; nausea; headache; clammy, moist skin; fainting, and
- Heat stroke - hot dry skin; high and rising body temperature; mental confusion; unconsciousness. May be fatal.

### 9.4.2 Prevention

If possible, acclimatize to heat levels by starting with short stays. Salt supplements are needed only during the first few days of acclimatization and may be acquired by additional light salt to food or drink. Avoid alcoholic beverages, but increase other liquid intake. Leave area immediately if feeling any of above symptoms.

## 9.5 Noise

Noise levels can be very high in some plant areas. The turbine building and other buildings with high speed equipment and mechanical maintenance areas are very common areas of high noise. Levels above 90 dBA may cause temporary hearing reduction, or if extended over a period of years, may result in a permanent hearing loss.

The best protection for short term exposure is the proper use of hearing protection devices (ear plugs or muffs).

## 9.6 Oxygen Limited Environments

Oxygen limited environments are those in which there is insufficient oxygen to sustain life. The lowest oxygen concentration in air permitted by OSHA is 19.5%.

Oxygen deficiencies may be due to oxygen displacement, reduced partial pressure of oxygen (such as at high altitude) and oxygen consumption. Normally the most common cause of oxygen limited environments at power plants would be due to displacement. Such areas may be deliberately oxygen deficient such as the drywell around a reactor or may be accidentally deficient, such as the interior of a tank containing dense fumes.

Prior to entering potentially oxygen limited environments, remote measurements of the oxygen level should be made. If this is not possible, an initial entry should be made using air supplied respirators to obtain direct measurements. Take time to be sure of the adequacy of the environment because an oxygen deficiency may not be sensed and is usually fatal.

Standard safety procedures require a tag authorizing entrance to be posted at the entrance to confined spaces and spaces that are normally oxygen deficient.

## 9.7 Electrical Shock

Electrical shock most commonly occurs from working on open wires, switches, etc. while components are energized and from the use of unsafe extension cords and temporary service leads.

Prevention includes treating all open electrical components as energized.

## 9.8 Compressed Gases

Hazards arise from cylinder rupture, gas leaks, cylinder mix-ups.

Safety actions include carefully checking labels, properly securing containers, avoiding compressed gases in confined spaces.

## 9.9 Falls

Safety reports indicate that the most frequently treated injuries at nuclear power plants are those resulting from falling and tripping. Avoid these injuries by taking time to observe the area for potential hazards that could cause falling and tripping; checking for proper securing of ladders, temporary flooring and scaffolding; and by moving about at a safe pace for the conditions.

## 9.10 General Safety Practices

General safety practices for industrial hazards parallel those employed for radiation protection including equipment, postings and permits.

### 9.10.1 Safety Equipment

Major items of safety equipment routinely

required at most sites include:

- Hardhats,
- Eye protection,
- Ear protection, and
- Sturdy shoes (Safety shoes are usually optional, but strongly recommended).

### 9.10.2 Posting

Posting and identifying industrial safety hazards is analogous to posting and identifying radiological hazards. The postings typically identify the hazard and the requirements for authorized entry.

### 9.10.3 Tagging

Tagging material and equipment to prevent unsafe use is a standard practice at all sites. A RED Danger tag is universally used to prevent operation or movement of an item or piece of equipment.

### 9.10.4 Permits

Permits are required to control operations with high chance for industrial safety problems. Permits are required for operations such as, welding, scaffolding, and confined space entry.

## 9.11 NRC and OSHA Memorandum of Understanding

A Memorandum of Understanding exists between the NRC and OSHA relating to occupational safety at NRC licensed facilities. The MOU is described in USNRC Information Notice 88-100 of December 23, 1988, and delineates general areas of overlapping/supporting responsibility between the NRC and OSHA to minimize work place hazards. The MOU helps to elevate safety issues to license management. The MOU appears in Appendix 9-1.

MSDS for HYDROFLUORIC ACID Page 1

1 - PRODUCT IDENTIFICATION

PRODUCT NAME: HYDROFLUORIC ACID
FORMULA: HF
FORMULA WT: 20.01
CAS NO.: 7664-39-3
NIOSH/RTECS NO.: MW7875000
COMMON SYNONYMS: HYDROGEN FLUORIDE SOLUTION
PRODUCT CODES: 5368,9563,9566,9564,9560,9567,4804,9568,9572
EFFECTIVE: 12/11/86
REVISION #03

PRECAUTIONARY LABELLING
BAKER SAF-T-DATA(TM) SYSTEM

HEALTH - 4 EXTREME (POISON)
FLAMMABILITY - 0 NONE
REACTIVITY - 2 MODERATE
CONTACT - 4 EXTREME (CORROSIVE)
HAZARD RATINGS ARE 0 TO 4 (0 = NO HAZARD; 4 = EXTREME HAZARD).

LABORATORY PROTECTIVE EQUIPMENT

GOGGLES & SHIELD; LAB COAT & APRON; VENT HOOD, PROPER GLOVES

PRECAUTIONARY LABEL STATEMENTS

POISON DANGER
MAY BE FATAL IF SWALLOWED
REACTS WITH WATER, LIBERATING HEAT.
EXTREMELY HAZARDOUS LIQUID AND VAPOR CAUSES SEVERE BURNS
WHICH MAY NOT BE IMMEDIATELY PAINFUL OR VISIBLE
EXCEPTIONAL HEALTH AND CONTACT HAZARDS - READ MATERIAL SAFETY DATA SHEET
DO NOT GET IN EYES, ON SKIN, ON CLOTHING.
DO NOT BREATHE VAPOR. KEEP IN TIGHTLY CLOSED CONTAINER IN A COOL AREA.
USE WITH ADEQUATE VENTILATION. WASH THOROUGHLY AFTER HANDLING
IN CASE OF SPILL, FLUSH AWAY BY FLOODING WITH WATER APPLIED QUICKLY TO
ENTIRE SPILL. NEUTRALIZE WASHINGS WITH LIME OR SODA ASH.

SAF-T-DATA(TM) STORAGE COLOR CODE: WHITE (CORROSIVE)

2 - HAZARDOUS COMPONENTS

| COMPONENT | % | CAS NO. |
|---|---|---|
| HYDROFLUORIC ACID | 45-55 | 7664-39-3 |

3 - PHYSICAL DATA

**Figure 9-1a Sample MSDS for Hydrofluoric Acid.**

MSDS for HYDROFLUORIC ACID Page 2

BOILING POINT: 108 C ( 226 F) VAPOR PRESSURE(MM HG): ~14

MELTING POINT: -35 C ( -31 F) VAPOR DENSITY(AIR=1): 1.97

SPECIFIC GRAVITY: 1.19 (H2O=1) EVAPORATION RATE: N/A (BUTYL ACETATE=1)

SOLUBILITY(H2O): COMPLETE (IN ALL PROPORTIONS) % VOLATILES BY VOLUME: 100

APPEARANCE & ODOR: COLORLESS,FUMING LIQUID WITH A SHARP ODOR.

4 - FIRE AND EXPLOSION HAZARD DATA

FLASH POINT (CLOSED CUP N/A NFPA 704M RATING: 4-0-0

FLAMMABLE LIMITS: UPPER - N/A % LOWER - N/A %

FIRE EXTINGUISHING MEDIA
USE EXTINGUISHING MEDIA SUITABLE FOR SURROUNDING FIRE. WARNING: APPLY WATER IN FLOODING QUANTITIES FROM AS FAR A DISTANCE AS POSSIBLE IN THE FORM OF A FOG. DO NOT USE A WATER STREAM.

SPECIAL FIRE-FIGHTING PROCEDURES
FIREFIGHTERS SHOULD WEAR PROPER PROTECTIVE EQUIPMENT AND SELF-CONTAINED BREATHING APPARATUS WITH FULL FACEPIECE OPERATED IN POSITIVE PRESSURE MODE. MOVE CONTAINERS FROM FIRE AREA IF IT CAN BE DONE WITHOUT RISK.
USE WATER TO KEEP FIRE-EXPOSED CONTAINERS COOL.

UNUSUAL FIRE & EXPLOSION HAZARDS
A VIOLENT EXOTHERMIC REACTION OCCURS WITH WATER. SUFFICIENT HEAT MAY BE PRODUCED TO IGNITE COMBUSTIBLE MATERIALS.
REACTS WITH MOST METALS TO PRODUCE HYDROGEN GAS, WHICH CAN FORM AN EXPLOSIVE MIXTURE WITH AIR.

TOXIC GASES PRODUCED
HYDROGEN FLUORIDE, HYDROGEN GAS

5 - HEALTH HAZARD DATA

TLV LISTED DENOTES CEILING LIMIT.

THRESHOLD LIMIT VALUE (TLV/TWA): 2.5 MG/M3 ( 3 PPM)

PERMISSIBLE EXPOSURE LIMIT (PEL): 2 MG/M3 ( 3 PPM)

TOXICITY: LC50 (INHL-MOUSE-1H) (PPM) - 456
LC50 (INHL-RAT-1H) (PPM) - 1276

CARCINOGENICITY: NTP: NO IARC: NO Z LIST: NO OSHA REG: NO

**Figure 9-1b Sample MSDS for Hydrofluoric Acid.**

MSDS for HYDROFLUORIC ACID Page 3

EFFECTS OF OVEREXPOSURE
VAPORS MAY BE IRRITATING TO SKIN, EYES, NOSE AND THROAT.
INHALATION OF VAPORS MAY CAUSE SEVERE IRRITATION OR BURNS OF THE RESPIRATORY SYSTEM, PULMONARY EDEMA, OR LUNG INFLAMMATION.
LIQUID AND VAPOR CAUSE SEVERE BURNS WHICH MAY NOT BE IMMEDIATELY PAINFUL OR VISIBLE.
SUBSTANCE IS READILY ABSORBED THROUGH SKIN, PENETRATING SKIN TO ATTACK UNDERLYING TISSUES AND BONE.
INGESTION MAY CAUSE SEVERE BURNS TO MOUTH, THROAT, AND STOMACH.
MAY HAVE ADVERSE EFFECT ON KIDNEY FUNCTION AND MAY BE FATAL.
CHRONIC EFFECTS OF EXPOSURE MAY INCLUDE HYPOCALCEMIA, BONE AND JOINT CHANGES.
TARGET ORGANS
EYES, SKIN, RESPIRATORY SYSTEM
MEDICAL CONDITIONS GENERALLY AGGRAVATED BY EXPOSURE
PULMONARY DISEASE, KIDNEY DISORDERS
ROUTES OF ENTRY
INGESTION, INHALATION, SKIN CONTACT, EYE CONTACT, ABSORPTION
EMERGENCY AND FIRST AID PROCEDURES
CALL A PHYSICIAN.
IF SWALLOWED, DO NOT INDUCE VOMITING; IF CONSCIOUS, GIVE WATER, MILK, OR MILK OF MAGNESIA
IF INHALED, REMOVE TO FRESH AIR. IF NOT BREATHING, GIVE ARTIFICIAL RESPIRATION. IF BREATHING IS DIFFICULT, GIVE OXYGEN
FOR ACID IN THE EYES
1. IRRIGATE EYES FOR AT LEAST 15 MINUTES WITH COPIOUS QUANTITIES OF WATER, KEEPING EYELIDS APART AND AWAY FROM EYEBALLS DURING IRRIGATION.
2. GET COMPETENT MEDICAL ATTENTION IMMEDIATELY, PREFERABLY AN EYE SPECIALIST.
3. IF A PHYSICIAN IS NOT IMMEDIATELY AVAILABLE, APPLY ONE OR TWO DROPS OF 0.5% PONTOCAINE HYDROCHLORIDE* SOLUTION FOLLOWED BY A SECOND IRRIGATION FOR 15 MINUTES. USE NONE OF THE SOLUTIONS DESCRIBED FOR SKIN TREATMENT. USE NO OILS OR GREASES UNLESS INSTRUCTED TO DO SO BY A PHYSICIAN.
* PONTOCAINE HYDORCHLORIDE IS A TRADE NAME FOR TETRACAINE HYDROCHLORIDE,
MERCK INDEX MONOGRAPH 8904, SOLD BY WINTHROP LABORATORIES, N.Y.C.
FOR ACID BURNS TO THE BODY
1. REMOVE THE VICTIM FROM THE CONTAMINATED AREA ANDIMMEDIATELY PLACE HIM UNDER A SAFETY SHOWER OR WASH HIM WITH A WATER HOSE, WHICHEVER IS AVAILABLE.
2. REMOVE ALL CONTAMINATED CLOTHING.
3. KEEP WASHING WITH LARGE AMOUNTS OF WATER FOR MINIMUM OF 15 TO 20 MINUTES.
4. HAVE SOMEONE MAKE ARRANGEMENTS FOR MEDICAL ATTENTION WHILE YOU CONTINUE FLUSHING THE AFFECTED AREA WITH WATER.
5 A) IF AVAILABLE, AFTER THOROUGH WASHING, THE BURNED AREA SHOULD BE IMMERSED IN A SOLUTION OF 0.2% ICED AQUEOUS HYAMINE 1622 ** OR 0.13% ICED AQUEOUS ZEPHIRAN CHLORIDE ***. IF IMMERSION IS NOT PRACTICAL, TOWELS SHOULD BE SOAKED WITH ONE OF THE ABOVE SOLUTIONS AND USED AS COMPRESSES FOR THE BURNED AREA. IDEALLY COMPRESSES SHOULD BE CHANGED EVERY 2 MINUTES.
5. B) AN ALTERNATIVE TREATMENT TO 5A IS FOR THE PHYSICIAN TO

**Figure 9-1c Sample MSDS for Hydrofluoric Acid.**

MSDS for HYDROFLUORIC ACID Page 4

INJECT STERILE 10% AQUEOUS CALCIUM GLUCONATE SOLUTION SUBCUTANEOUSLY BENEATH, AROUND, AND IN THE BURNED AREA. INITIALLY USE NO MORE THAN 0.5 CC PER SQUARE CENTIMETER AND DO NOT DISTORT APPEARANCE OF SKIN. IF PAIN IS NOT COMPLETELY RELIEVED, ADDITIONAL TREATMENT IS INDICATED.

6. SEEK MEDICAL ATTENTION AS SOON AS POSSIBLE FOR ALL BURNS REGARDLESS OF HOW MINOR THEY MAY APPEAR INITIALLY.

**HYAMINE 1622 IS A TRADE NAME FOR TETRACAINE BENZETHONIUM CHLORIDE,
MERCK INDEX MONOGRAPH 1078, A QUATERNARY AMMONIUM COMPOUND SOLD BY ROHM HAAS, PHILADELPHIA.

***ZEPHIRAN CHLORIDE IS A TRADE NAME FOR BENZALKONIUM CHLORIDE, MERCK INDEX
MONOGRAPH 1059, ALSO A QUATERNARY AMMONIUM COMPOUND, SOLD BY WINTHROP LABORATORIES, N.Y C.

## 6 - REACTIVITY DATA

STABILITY: STABLE HAZARDOUS POLYMERIZATION: WILL NOT OCCUR

CONDITIONS TO AVOID: MOISTURE

INCOMPATIBLES: ALKALIES, ORGANIC MATERIALS, MOST COMMON METALS,
RUBBER, LEATHER, FLUORINE, WATER,
STRONG BASES, CARBONATES, SULFIDES, CYANIDES,
OXIDES OF SILICON, ESP. GLASS, CONCRETE, SILICA

DECOMPOSITION PRODUCTS: HYDROGEN FLUORIDE, HYDROGEN

## 7 - SPILL AND DISPOSAL PROCEDURES

STEPS TO BE TAKEN IN THE EVENT OF A SPILL OR DISCHARGE
WEAR SELF-CONTAINED BREATHING APPARATUS AND FULL PROTECTIVE CLOTHING. STOP LEAK IF YOU CAN DO SO WITHOUT RISK. VENTILATE AREA. NEUTRALIZE SPILL WITH SODA ASH OR LIME. WITH CLEAN SHOVEL, CAREFULLY PLACE MATERIAL INTO CLEAN, DRY CONTAINER AND COVER; REMOVE FROM AREA. FLUSH SPILL AREA WITH WATER.
J. T. BAKER NEUTRASOL(R) "LOW NA+" ACID NEUTRALIZER IS RECOMMENDED FOR SPILLS OF THIS PRODUCT.

DISPOSAL PROCEDURE
DISPOSE IN ACCORDANCE WITH ALL APPLICABLE FEDERAL, STATE, AND LOCAL ENVIRONMENTAL REGULATIONS.

EPA HAZARDOUS WASTE NUMBER: U134 (TOXIC WASTE)

## 8 - PROTECTIVE EQUIPMENT

VENTILATION: USE GENERAL OR LOCAL EXHAUST VENTILATION TO MEET TLV REQUIREMENTS.

RESPIRATORY PROTECTION: RESPIRATORY PROTECTION REQUIRED IF AIRBORNE CONCENTRATION EXCEEDS TLV. AT CONCENTRATIONS UP

**Figure 9-1d Sample MSDS for Hydrofluoric Acid.**

MSDS for HYDROFLUORIC ACID Page 5

TO 20 PPM, A CHEMICAL CARTRIDGE RESPIRATOR WITH ACID CARTRIDGE AND DUST/MIST FILTER IS RECOMMENDED ABOVE THIS LEVEL, A SELF-CONTAINED BREATHING APPARATUS IS ADVISED

EYE/SKIN PROTECTION SAFETY GOGGLES AND FACE SHIELD, UNIFORM, PROTECTIVE SUIT, NEOPRENE GLOVES ARE RECOMMENDED.

9 - STORAGE AND HANDLING PRECAUTIONS

SAF-T-DATA(TM) STORAGE COLOR CODE WHITE (CORROSIVE)

SPECIAL PRECAUTIONS
KEEP CONTAINER TIGHTLY CLOSED. STORE IN CORROSION-PROOF AREA.
ISOLATE FROM INCOMPATIBLE MATERIALS
STORE AT 38 C OR BELOW.
PROTECT FROM FREEZING.
HYDROFLUORIC ACID IS INCOMPATIBLE WITH GLASS AND ALL SILICON-BEARING
MATERIALS AND SHOULD NEVER BE TRANSFERRED TO GLASS CONTAINERS. MATERIAL
SHOULD REMAIN IN THE ORIGINAL POLYETHYLENE CONTAINER. UNLINED STEEL
TANKS IN HYDROFLUORIC SERVICE ARE SUBJECT TO INDISCRIMINATE HYDROGEN
BLISTERING AND SHOULD ROUTINELY BE INSPECTED AND REPAIRED.

10 - TRANSPORTATION DATA AND ADDITIONAL INFORMATION

DOMESTIC (D O T )

PROPER SHIPPING NAME HYDROFLUORIC ACID, SOLUTION
HAZARD CLASS CORROSIVE MATERIAL (LIQUID)
UN/NA UN1790
LABELS CORROSIVE
REPORTABLE QUANTITY 100 LBS.

INTERNATIONAL (I M O.)

PROPER SHIPPING NAME HYDROFLUORIC ACID, SOLUTION
HAZARD CLASS 8, 6 1
UN/NA UN1790
LABELS CORROSIVE, POISON

**Figure 9-1e Sample MSDS for Hydrofluoric Acid.**

# CHAPTER 9

# APPENDIX 9-1

# NRC Memorandum of Understanding with OSHA

NRC and OSHA Memorandum of Understanding (MOU)

The NRC has a "Memorandum of Understanding" or MOU with OSHA. According to this MOU, NRC personnel may identify safety concerns within the area of OSHA responsibility or may receive complaints from an employee about OSHA-covered working conditions. They may bring these matters to the attention of licensee management, or elevate OSHA safety issues to the attention of NRC Regional management when appropriate.

Addessees:
NRC Information Notice No. 88-100 (December 23, 1988) was addressed to all major nuclear materials licensees and utilities holding construction permits and operating licenses.

Purpose:
This notice is intended to inform all licensees of a new Memorandum of Understanding (MOU) between NRC and the U.S. Occupational Safety and Health Administration (OSHA) that provides guidelines for coordination of interface activities between the two Agencies (NRC Information Notice No. 88-100, December 23, 1988). It is expected that licensees will review this information, and distribute the notice to responsible radiation safety and industrial hygiene staffs. However, suggestions contained in this information notice do not constitute new NRC requirements, and no written response is required.

Discussion:
Both NRC and OSHA have jurisdiction over occupational safety and health at NRC-licensed facilities. Because it is not always practical to sharply identify boundaries between the nuclear and radiological safety that NRC regulates and industrial safety that OSHA regulates, a coordinated interagency effort can ensure against gaps in the protection of workers, and at the same time, avoid duplication of effort. The new MOU replaces an existing procedure which outlined the NRC's and OSHA's interagency activities.

Although NRC does not specifically examine industrial safety during inspections of radiological and nuclear safety, NRC personnel may identify safety concerns within the area of OSHA responsibility, or may receive complaints from an employee about OSHA-covered working conditions. In such instances, NRC will bring the matter to the attention of licensee management or monitor corrective action when appropriate. If significant safety concerns are identified, or if the licensee demonstrates a pattern of unresponsiveness to identified concerns, the NRC regional office will inform the appropriate OSHA regional office. Also, when known, NRC inspectors will encourage licensees to report to OSHA accidents resulting in a fatality or multiple hospitalizations. It is not the intent of the Commission that NRC inspectors perform the role of OSHA inspectors; however, they are to elevate OSHA safety issues to the attention of OSHA Regional management when appropriate.

Similarly, OSHA Regional Offices will inform the appropriate NRC Regional Office of matters which are in the purvue of NRC, when these matters come to their attention during Federal or State safety and health inspections or through complaints.

# CHAPTER 10

# PHYSICAL PROTECTION

# AND EMERGENCIES

# 10.0 PHYSICAL PROTECTION AND EMERGENCIES

## 10.0.1 Purpose

Provide an overview of the physical protection controls and procedures that will be encountered at a nuclear power station and some fuel cycle facilities and the general procedures for responding to emergencies, drills, and incidents.

## 10.0.2 Objectives

At the conclusion of this topic, course participants should be able to:

- Describe the purpose of physical protection,
- Describe the levels of access control,
- Describe in general the requirements for entry and expected conduct in protected/ vital and material access areas,
- Describe safeguards information and classified information and how it is to be handled,
- Describe the general actions taken for various emergencies, incidents and drills, and
- List situations that require evacuation of the work area.

## 10.0.3 Reference

- Title 10 of the Code of Federal Regulations Part 73 - Physical Protection of Plants and Materials

## 10.1 Physical Protection ("Security") of Plants and Materials

The purpose of physical protection is to:

- Protect against acts of radiological sabotage,
- Prevent theft of special nuclear material, and
- Protect safeguards and classified information against unauthorized release.

### 10.1.1 Definitions

- "Authorized Individual" is an individual ...who has been designated in writing by the licensee to have... unescorted access...
- "Classified Information" is information that is required to be protected against unauthorized disclosure under Executive Order 12356 or the Atomic Energy Act of 1954, as amended. (Classified information is encountered only at fuel cycle facilities that possess a formula quantity of special nuclear material)
- "Isolation Zone" is an area adjacent to a physical barrier which is clear of all objects which could shield an individual.
- "Material Access Area" is a controlled area enclosed by barriers, where special nuclear material is present.
- "Physical Barrier" means fences, walls, ceilings and floors constructed of ...(specific materials, thicknesses, heights, etc.).
- "Protected Area" is an area encompassed by physical barriers to which access is controlled.
- "Safeguards Information" is data, not otherwise classified, which specifically identifies security measures for physical protection and location of certain equipment vital to plant operations.

- "Vital Area" is any area containing vital equipment.

- "Vital Equipment" is any equipment, system, device or material; the failure, destruction, or release of which could endanger the public by exposure to radiation.

### 10.1.2 Performance Capabilities

The licensee must be able to:

- Prevent unauthorized access of persons, vehicles and materials into material access, protected and vital areas by using detection and barrier systems,

- Permit only authorized activities and conditions within protected areas, material access areas, and vital areas by using controls and procedures, defined boundaries, detection, communication and surveillance subsystems, and by established schedules of authorized operations,

- Provide for authorized access and assure detection of and response to unauthorized penetrations of the protected area by using the above mentioned subsystems and functions

- Permit only authorized control/movement of special nuclear material and

- Provide response capabilities to assure the above mentioned items are achieved.

### 10.1.3 General Levels of Access Control

The levels of access control are:

1. Owner (licensee) controlled property area:

   a. Can control, but areas outside protected area physical barriers are usually not considered an active part of physical protection, and

   b. Access routes and general boundaries are posted with warning and restriction signs.

2. Protected Area:

   a. Area encompassed by physical barriers (such as a fence) and to which all points of personnel and vehicles access are controlled,

   b. Identification and search of all vehicles, individuals and packages for firearms, explosives or incendiary devices shall be made.

   c. Rules of conduct:

      (1) No cameras, weapons, explosives, incendiary devices, alcohol, or drugs

      (2) I.D. badge must be displayed at all times

      (3) If unescorted access is not granted, must stay within view of escort at all times

      (4) Don't challenge system (i.e. stay away from fence/barriers)

3. Vital Area

   a. Area containing vital equipment whose failure, destruction, or loss of service could endanger the public by exposure to radiation.

   b. Vital area is normally within the protected area and is enclosed by a wall. If not within protected area it still must require access through two

physical barriers.

c. Entrance is normally via a card reader.

d. Areas monitored by closed circuit video systems.

e. Rules of conduct:

(1) Since the vital area is within a protected area, all rules for protected areas apply.

(2) Don't pull on door before it unlocks

(3) Don't tailgate in or out on another card

4. Material Access Area

a. Any location which contains special nuclear material.

b. Material access areas must be located within the protected area so that access requires passage through at least three physical barriers.

c. Access to material access areas shall include at least two individuals and is limited to individuals who are authorized and require access to perform their duties.

d. Rules of conduct:

(1) ID badge must be displayed at all times and indicate authorization to access material access area.

(2) Must stay within view of escort at all times if unescorted access is not granted.

## 10.2 Safeguards Information

Safeguards information applies to information relating to the security plan and procedures, physical protection systems, vital safety equipment, and deployment of guards at the site.

Access to information must be on a "need-to-know" basis and must not be discussed with or divulged to unauthorized persons.

Such information must clearly identify that it is "safeguards information".

## 10.3 Classified Information

Classified information applies to information relating to:

1. material control and accountability
2. physical protection at fixed fuel facilities
3. in-transit protection of SSNM

For specific classification levels, reference "NRC Classification Guide for National Security Information Concerning Nuclear Materials and Facilities (CG-NMF-2).

Access to information requires a minimum of an NRC-L or DOE-L clearance, a "need-to-know" and must not be discussed with or divulged to unauthorized persons.

Such information must clearly identify that it is information classified, at a minimum, at the "Confidential" level.

## 10.4 Emergencies and Drills

Various alarms, sirens, and announcements are used, but there is some standardization toward:

- Wailing, warbling, or pulsing for radiological emergencies (unusual event, alert, site area emergency, and general emergency),

- Beeping (European police) or siren for fire alarms and medical or first-aid response,

- Bells or buzzer for local area problems, and

- Solid tone for all clear, a message, or test.

During an emergency or drill you are responsible for obeying the assembly, evacuation, or "stand-fast" orders given during site specific training or announced as part of the alarm. Make sure you know and understand the required response. Some generally consistent emergencies and responses are:

1. Radiological Emergency

   a. Exit area immediately and report to assembly area or area specified during the site specific training (listen for verbal instructions).

   b. There are four levels of radiological emergencies and the first two (unusual event and alert) are usually verbal announcements which require no (or limited) evacuation action. The higher two categories (site area emergency and general area emergency) usually require evacuation.

2. Criticality Alarm - certain fuel facilities authorized to possess critical mass quantities of special nuclear material are required to have alarming monitors that can detect radiation from an uncontrolled nuclear chain reaction (e.g., criticality). Generally, criticality alarms require the same response as other radiological emergencies.

3. Chemical Emergency - Some fuel cycle facilities use large quantities of highly corrosive chemicals (HF, $UF_6$, Ammonia etc) that could create dangerous vapor clouds if released. If you see, feel or smell such vapors (even if no alarm has sounded), exit the area immediately, notify licensee management (if necessary) and report to the assembly area or other area specified during site specific training.

4. Fire or Medical Alarm - wait for the verbal announcement if you cannot see a reason for the alarm. Take appropriate action if you can see the emergency.

5. Local Area Alarm - exit area immediately and report to health physics or industrial safety.

Unless assigned specific duties, stay out of the way of response teams and use your expertise only to prevent deterioration of serious conditions.

Personnel accountability for drills and emergencies is accomplished by the security department. That is one reason "tailgating" is not permitted.

## 10.5 Injuries

The primary concern is medical treatment and preservation of life rather than maintaining radiological controls.

Take steps to avoid complications by applying first aid, removing respiratory equipment, bypassing controls, as warranted.

Know how to make an announcement and request assistance (such as calling the control room, using the announcing system (Gaitronics) and notifying security).

Approval by health physics is required to enter a radiologically controlled area with any open wound or broken skin such as a cut or deep abrasion.

## 10.6 Incidents

The appropriate responses to the following incidents are:

1. Radioactive Spill Procedure (SWIMS)
   a. Stop the spill
   b. Warn others
   c. Isolate the area
   d. Minimize your exposure
   e. Secure non-filtered ventilation such as fans and windows
2. Area Radiation/Airborne Alarm - promptly leave the area and contact health physics if any local radiation alarm, such as from a RAM or CAM, occurs.
3. Off-Scale, lost, or damaged dosimetry
   a. Immediately inform others in the work area
   b. Promptly report to health physics even if the device appears to be operating properly.
   c. Many facilities treat greater than 3/4 scale as "off-scale"
4. Personnel or clothing contamination - standby and call/send for health physics assistance.
5. Respiratory Protection Problem - immediately leave the area and remove the mask as necessary to provide unencumbered breathing.
6. General Problem/Alarm - take action which will cause minimal interference with emergency operations and place you in an area of less concern or where exit is easy.


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